ASTRONOMY

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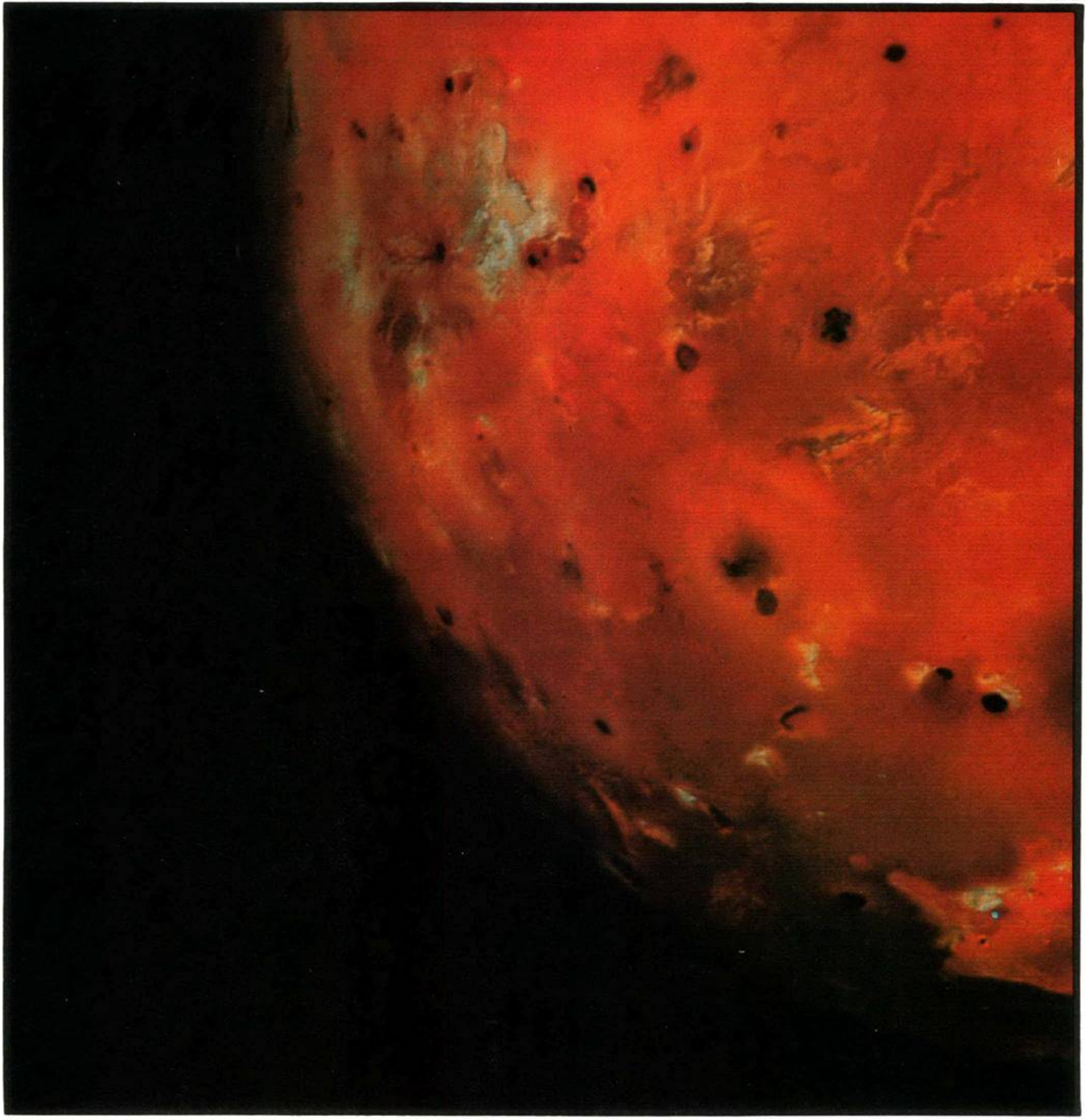
Meteorites and Our Solar System

My First Telescope

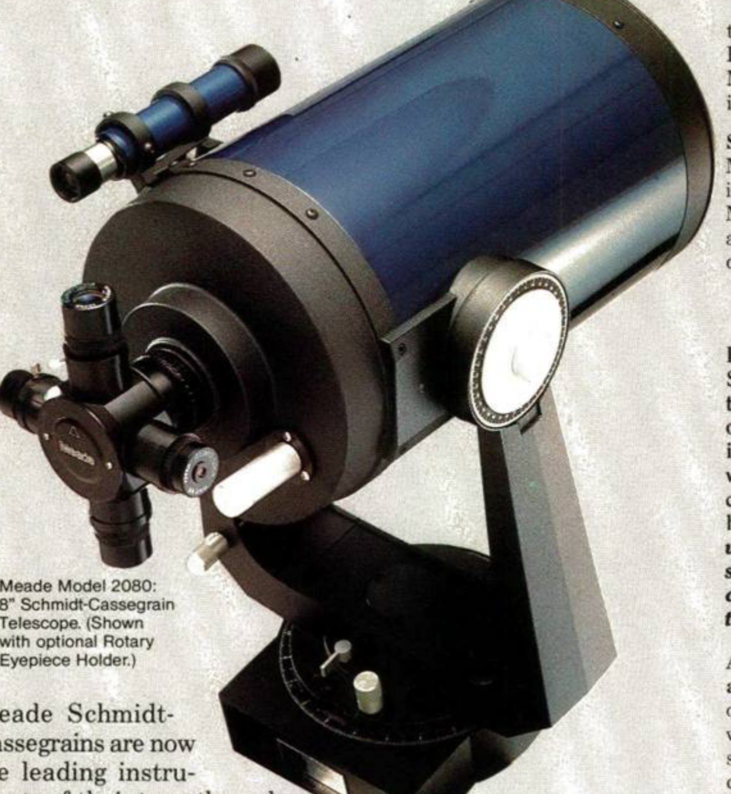
How Amateur Astronomers Measured an Asteroid

ICD# 08070 71574



Jupiter's Moon Io

Meade® 4", 8", and 10" Schmidt-Cassegrains: So technically advanced they're warranted for life.



Meade Model 2080: 8" Schmidt-Cassegrain Telescope. (Shown with optional Rotary Eyepiece Holder.)

Meade Schmidt-Cassegrains are now the leading instruments of their type throughout the World, and for one reason: precision. Precision in design, in engineering, and in manufacture. And, now Meade Instruments backs up this commitment to precision with a Warranty **valid for as long as you own your telescope.**

Consider the following technical advantages — advantages that have made Meade Schmidt-Cassegrains Number One worldwide.

Optical Design and Manufacture — Meade 4", 8", and 10" optical system designs utilize the latest, most modern computer-aided ray trace analysis. Analysis which showed us, for example, that by making the primary mirrors of Meade 8" and 10" Schmidt-Cassegrains 3% oversize, we could increase off-axis image brightness by 10% over competing models, aperture for aperture. As a result, the 8" Meade 2080 **without** high transmission coatings yields brighter off-center images than competing 8" telescopes **with** coatings. The 10" Meade 2120 yields off-center images almost as bright as competing 11" models, but with vastly superior portability and at substantially lower cost.

The standard worm-gear drive system of the Meade 8" Model 2080.

Meade diffraction-limited optics are polished to surface accuracies within 1/10-wavelength, and are manufactured and tested with the most precise optical test equipment available. Every 8" system, for example, is tested at 1000X on one of our laser autocollimators and corrected for extremely minute errors in the diffraction image – errors which are invisible to most observers at normal magnifications. Further, each 3-element optical set is **individually** hand-corrected to produce a knife-edge optical null and razor-straight bands under the Ronchi test. This battery of three independent optical tests assures that Meade Schmidt-Cassegrain optics are, without exception, the finest available in any commercial telescope.

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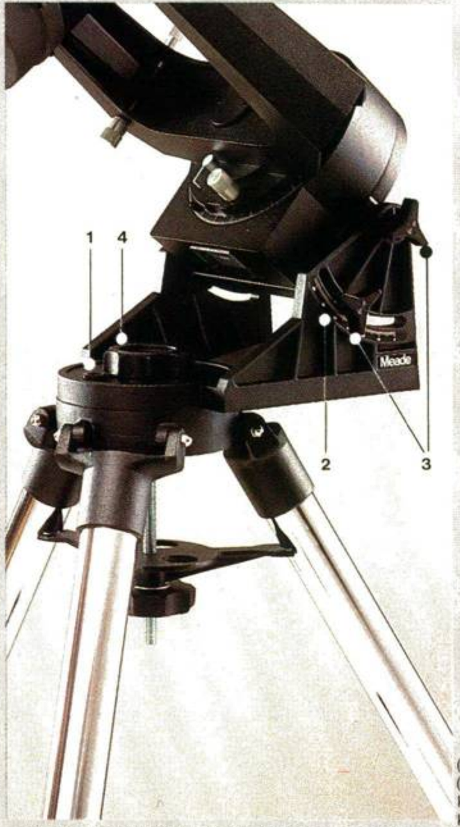
New LX (Long-Exposure) Drive System now Available on Meade 8" and 10" Schmidt-Cassegrains

For the most advanced astrophotographic applications, the new Meade LX Drive System is now available optionally at modest additional cost on the 8" Model 2080; the LX Drive System is now included as standard equipment at no additional charge on the Meade 10" Model 2120. The LX Drive includes custom gear components ground with extreme precision, and permits practical long-exposure photographs up to 2 hours' duration. ***The LX Drive System is warranted to equal or exceed the precision of any drive system available on any production Schmidt-Cassegrain telescope.***

Latitude scale of the Equatorial Wedge.

Advanced-Design Equatorial Wedge and Field Tripod Systems — The owner of a Meade Schmidt-Cassegrain will appreciate the attention to detail shown in the Meade Equatorial Wedge and Field Tripod. Each Wedge includes a latitude scale permitting accurate polar alignment of the telescope in a few **seconds,** not minutes. A universal bubble level, machined into the floor of the Wedge and also included as standard equipment, enables the observer to rapidly align the wedge/tripod system to the horizontal, without guesswork. Azimuth orientation is facilitated by the 360°-rotation capability of the Wedge on the Field Tripod — and by the fact that no wrenches or tools of any kind are required in the operation of 4" and 8" models, and only one hex wrench on 10" models.



The Meade Equatorial Wedge/Field Tripod System.

(1) Bubble level; (2) Latitude scale; (3) No-Tool-Required adjustment knobs; (4) Wedge-to-Tripod lock knob, permitting 360° Wedge adjustments in azimuth.

The Meade Field Tripod, variable in height from 30" to 44", allows comfortable observing in either seated or standing positions, and is almost universally regarded as the strongest, most rigid astronomical tripod yet developed. With its exceptionally low damping time, the Field Tripod is suitable for the most sensitive astrophotographic, as well as visual, applications.

Systems Engineering — Meade Schmidt-Cassegrain telescopes and their long list of related optional accessories were designed as a system of complementary components. The optional electric declination motor, for example, fits neatly in a cavity at the undersurface of one fork arm. Optional dew shields lock into a track pre-machined into the corrector cell of every 8" and 10" telescope. Other accessory systems, from sliding counterweights to the f/2.64 Schmidt Camera, attach directly to the standard telescopes without customer drilling or adaptation. The motivated observer will find an almost unlimited potential for growth, with an absolute minimum of observing time diverted to equipment maintenance and adjustment.

Great Nebula in Orion (M42). A 50-minute exposure on Ektachrome 400 through the Meade 8" Model 2080.

Lifetime Warranty — In the U.S.A. and Canada, Meade 4", 8", and 10" Schmidt-Cassegrain astronomical telescopes are **warranted for life** against defects in materials or manufacture. (Outside North America, see your Meade international distributor for details on his extended-term warranty.) The Meade General Catalog contains full details on this ultimate protection of your investment in astronomy.

Meade Dealers (hundreds located throughout the U.S.A. and Canada) carry a stock of Meade astronomical telescopes, spotting scopes, telephoto lenses, and accessories, and can offer you further technical information on the wide range of Meade research-quality optical systems — and at surprisingly competitive pricing levels. In the event of a dealer stock shortage on a particular item, we can normally ship to a dealer any Meade Schmidt-Cassegrain complete telescope or accessory within 24 hours.

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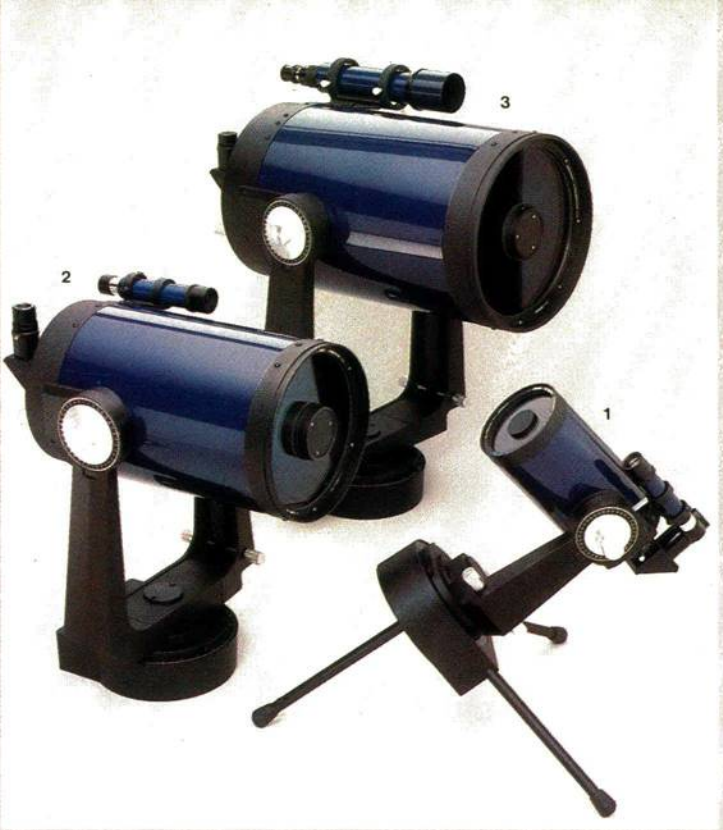
Meade Model 90B:
1000mm f/11 Maksutov Telephoto Lens



Meade Schmidt-Cassegrain Telescopes. (1) 4" Model 2044, with standard-equipment table tripod; (2) 8" Model 2080; (3) 10" Model 2120.

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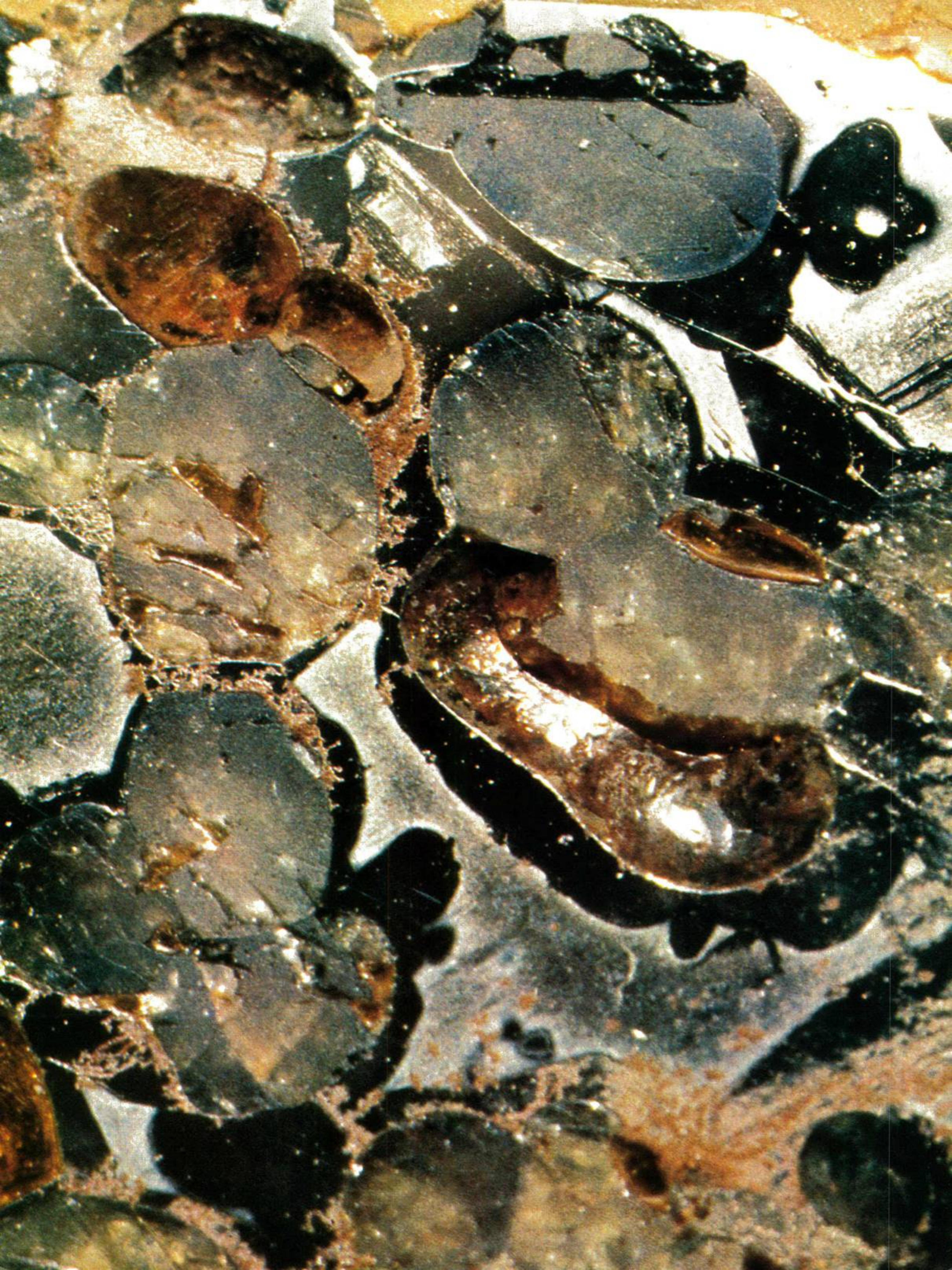

ASTRONOMY

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Cover: Space exploration gave planetary geologists the opportunity to study many strange surfaces, such as the sulfur-dominated crust of Jupiter's moon Io. But where does reality end and fantasy begin? This month, ASTRONOMY gives you glimpses of some scientifically possible worlds, starting on page 66. JPL/NASA photo. The lead features this month take a look at some samples of extraterrestrial material that we can actually handle — meteorites. These pages: The polished surface of a stony-iron meteorite. Photo by Jeffrey K. Wagner.

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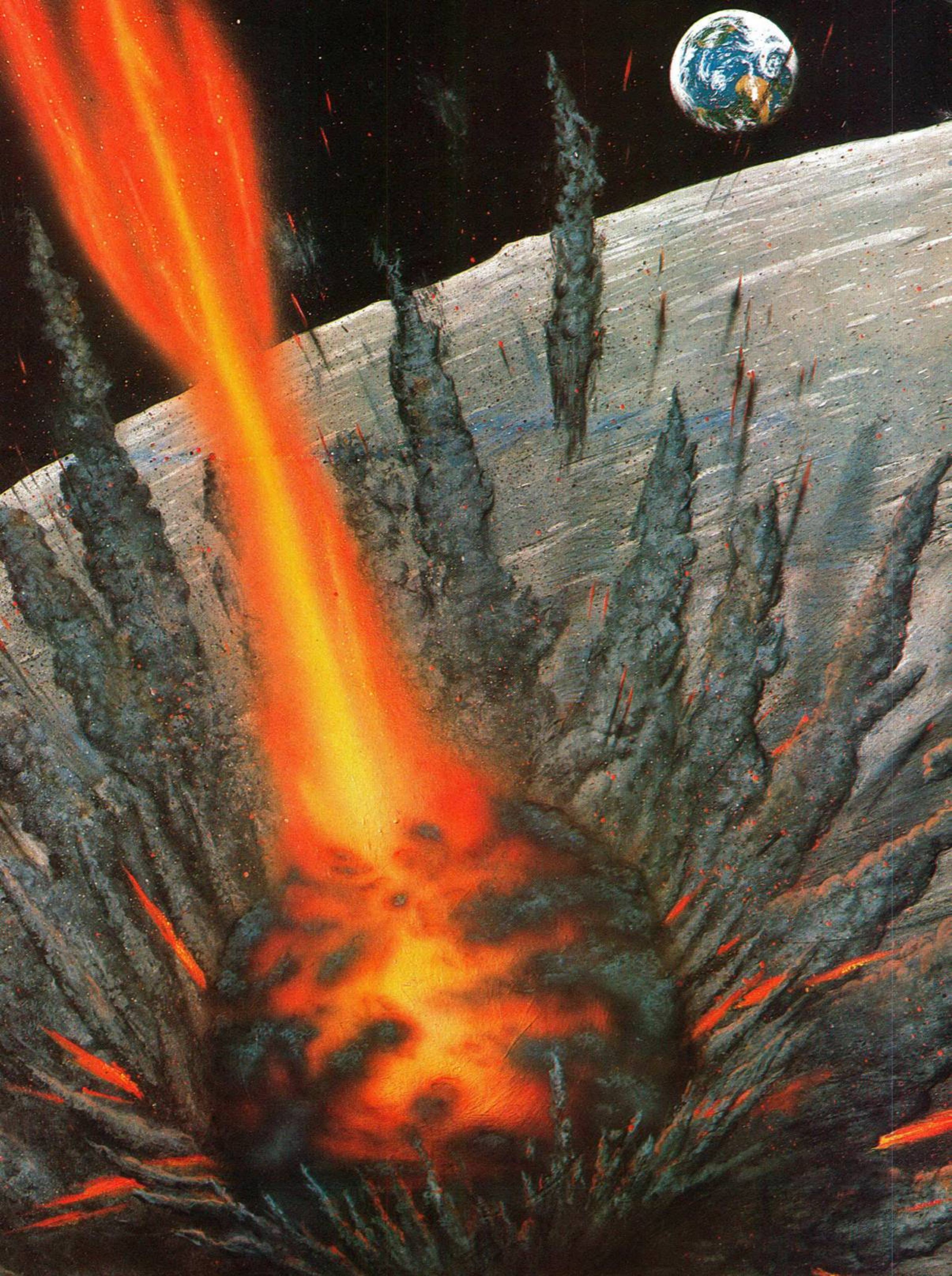
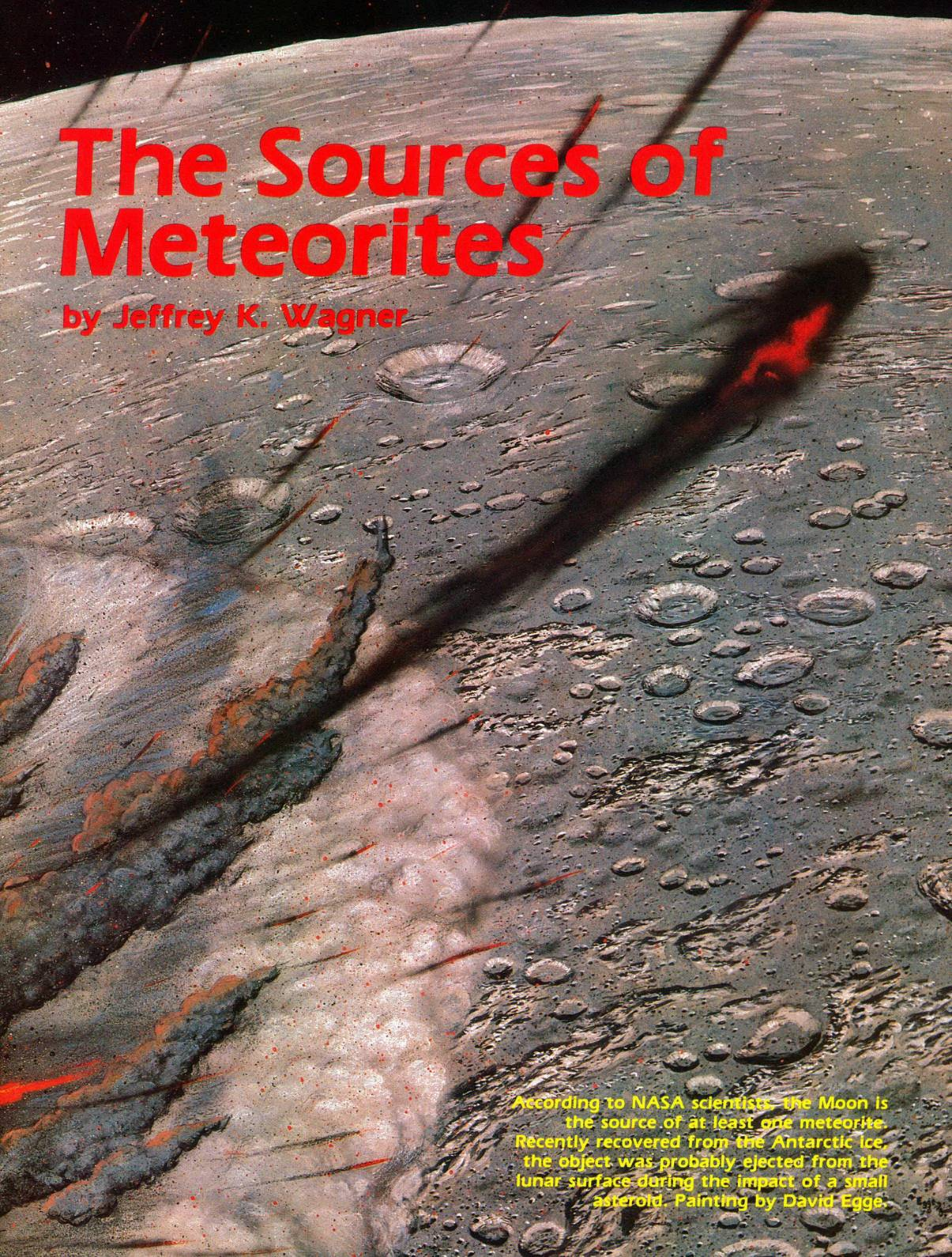
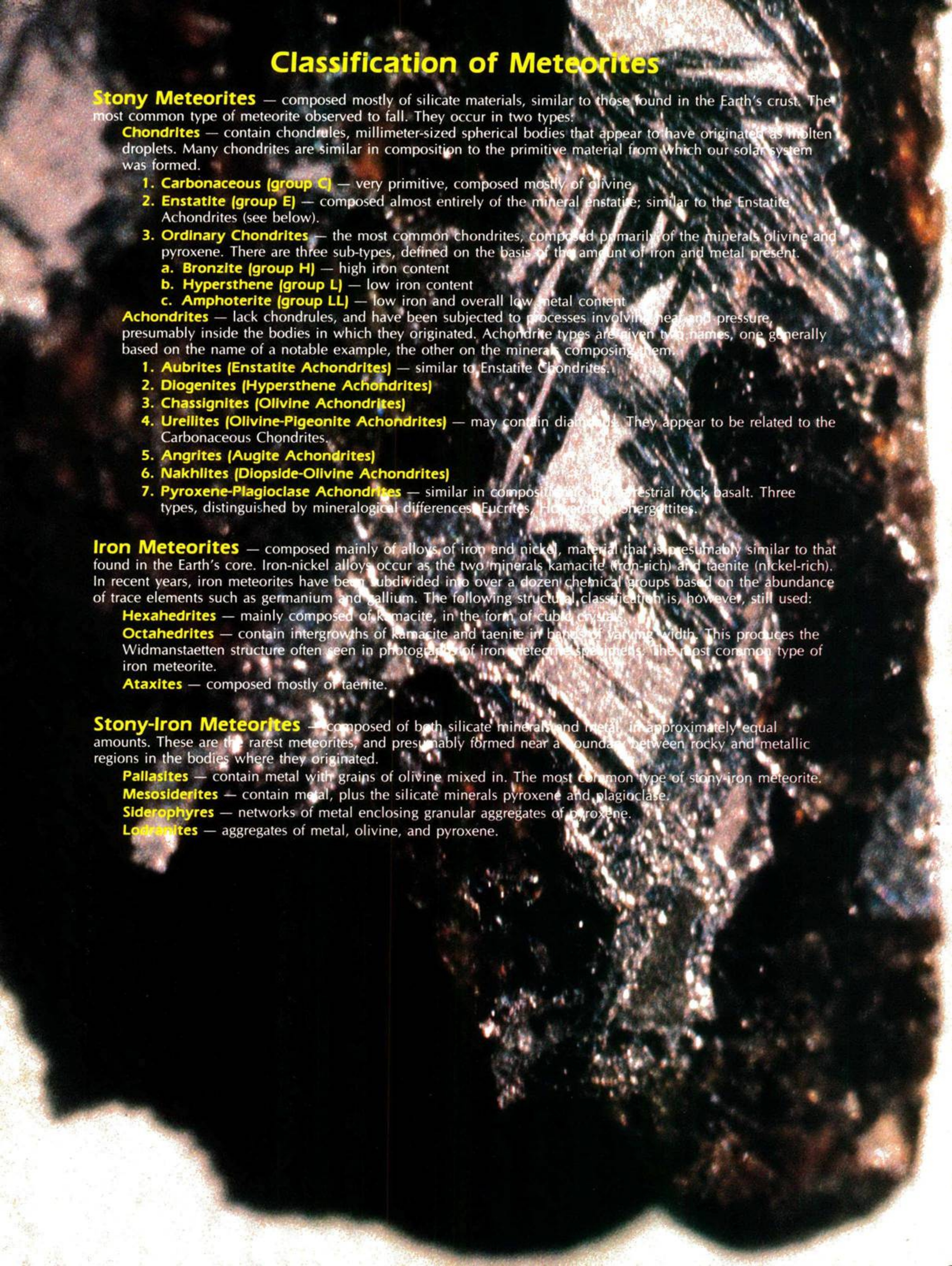


The Sources of Meteorites

by Jeffrey K. Wagner



According to NASA scientists, the Moon is the source of at least one meteorite. Recently recovered from the Antarctic ice, the object was probably ejected from the lunar surface during the impact of a small asteroid. Painting by David Egge.



Classification of Meteorites

Stony Meteorites — composed mostly of silicate materials, similar to those found in the Earth's crust. The most common type of meteorite observed to fall. They occur in two types:

Chondrites — contain chondrules, millimeter-sized spherical bodies that appear to have originated as molten droplets. Many chondrites are similar in composition to the primitive material from which our solar system was formed.

1. **Carbonaceous (group C)** — very primitive, composed mostly of olivine.
2. **Enstatite (group E)** — composed almost entirely of the mineral enstatite; similar to the Enstatite Achondrites (see below).
3. **Ordinary Chondrites** — the most common chondrites, composed primarily of the minerals olivine and pyroxene. There are three sub-types, defined on the basis of the amount of iron and metal present.
   - a. **Bronzite (group H)** — high iron content
   - b. **Hypersthene (group L)** — low iron content
   - c. **Amphoterite (group LL)** — low iron and overall low metal content

Achondrites — lack chondrules, and have been subjected to processes involving heat and pressure, presumably inside the bodies in which they originated. Achondrite types are given two names, one generally based on the name of a notable example, the other on the minerals composing them.

1. **Aubrites (Enstatite Achondrites)** — similar to Enstatite Chondrites.
2. **Diogenites (Hypersthene Achondrites)**
3. **Chassignites (Olivine Achondrites)**
4. **Ureilites (Olivine-Pigeonite Achondrites)** — may contain diamonds. They appear to be related to the Carbonaceous Chondrites.
5. **Angrites (Augite Achondrites)**
6. **Nakhlites (Diopside-Olivine Achondrites)**
7. **Pyroxene-Plagioclase Achondrites** — similar in composition to the terrestrial rock basalt. Three types, distinguished by mineralogical differences: Eucrites, Howardites, Shergottites.

Iron Meteorites — composed mainly of alloys of iron and nickel, material that is presumably similar to that found in the Earth's core. Iron-nickel alloys occur as the two minerals kamacite (iron-rich) and taenite (nickel-rich). In recent years, iron meteorites have been subdivided into over a dozen chemical groups based on the abundance of trace elements such as germanium and gallium. The following structural classification is, however, still used:

Hexahedrites — mainly composed of kamacite, in the form of cubic crystals.

Octahedrites — contain intergrowths of kamacite and taenite in bands of varying width. This produces the Widmanstaetten structure often seen in photographs of iron meteorite specimens. The most common type of iron meteorite.

Ataxites — composed mostly of taenite.

Stony-Iron Meteorites — composed of both silicate minerals and metal, in approximately equal amounts. These are the rarest meteorites, and presumably formed near a boundary between rocky and metallic regions in the bodies where they originated.

Pallasites — contain metal with grains of olivine mixed in. The most common type of stony-iron meteorite.

Mesosiderites — contain metal, plus the silicate minerals pyroxene and plagioclase.

Siderophyres — networks of metal enclosing granular aggregates of pyroxene.

Lodranites — aggregates of metal, olivine, and pyroxene.

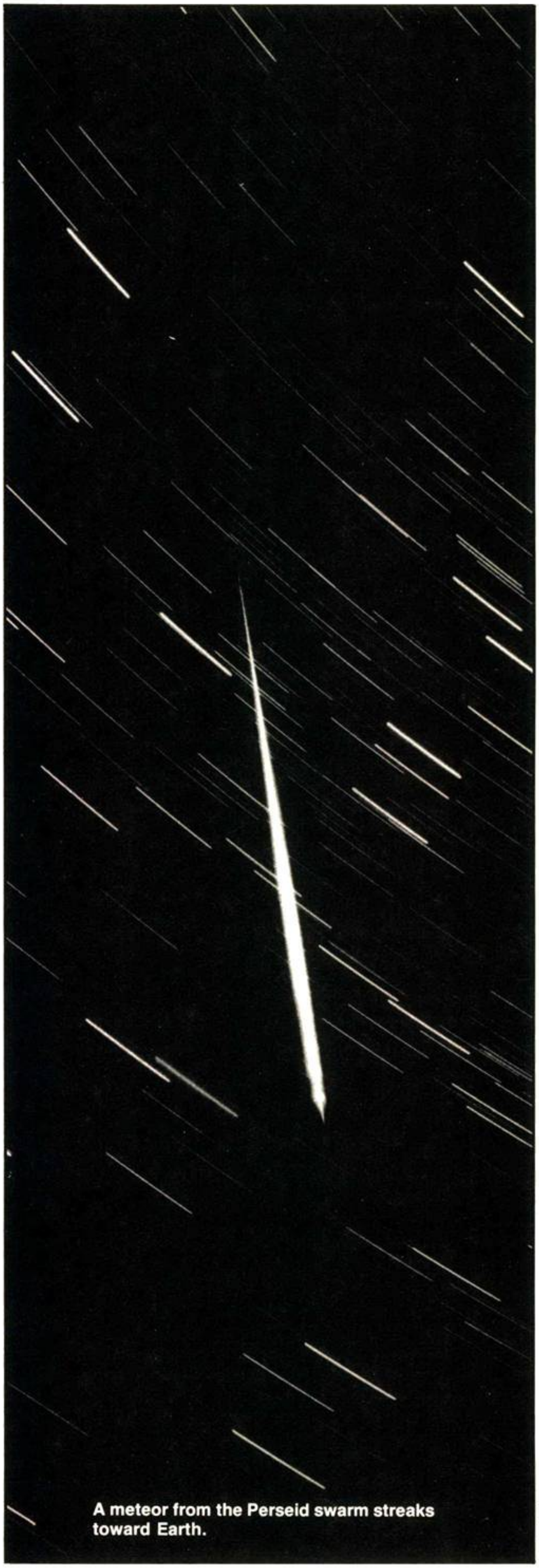
Until recent decades, we gained our knowledge about the solid bodies in the solar system other than our planet at a painfully slow rate. Relatively few astronomers were interested in the solar system, and techniques for studying its objects were limited to visual observation of their surface features and basic studies using spectroscopy. During this period, geologists busily studied Earth and developed sophisticated techniques for learning about its composition, structure, and history. Since the beginning of the Space Age, geologists and astronomers have joined forces to study the solar system, creating the science of planetary geology.

Today, planetary geologists apply the same techniques to other planets that they have long applied to Earth. An experienced geologist, for example, can make a detailed interpretation of a remote section of our globe by studying aerial or space photographs. Similarly, now that blurred telescopic views have been supplemented by high-resolution photographs of most of the solar system's major bodies, the same interpretive techniques have given us a remarkable understanding of the geology of a number of planets and satellites.

While we can gain much geological information by studying photographs of a planet, we could gain far more if a geologist could visit its surface or study rock samples that originated there. To date, we've returned samples from only one solar system body — the Moon. Over 800 pounds of lunar material were brought back during the Apollo program, material that has undergone scientific study of almost every conceivable sort. Despite the wealth of scientific information the Apollo materials have provided, these samples have several drawbacks: They required a tremendous expenditure of funds to obtain, they sample only one extraterrestrial body, and finally, since the Moon has experienced extensive geological changes, the Apollo samples are not as old and unaltered as many researchers would like.

In contrast to the Apollo samples, there is a large quantity of extraterrestrial material already on Earth that became available at no cost — the meteorites. Most meteorites bear little resemblance to the Apollo samples and occur in a wide variety of compositions. Many are very old; some have remained virtually unchanged since the time of the solar system's formation. The Allende meteorite is an example of the research value of "stones from space." In early 1969, over two tons of material fell near the town Allende in Mexico. (Meteorites are named for the location of their fall.) Using the most advanced equipment available, hundreds of scientists studied samples of Allende. They treated the event as a dress rehearsal for the study of the upcoming Apollo 11 samples. Allende, a relatively rare and interesting meteorite type, has yielded abundant scientific results, particularly concerning the conditions prevailing when our solar system was forming. Some researchers might argue that Allende's value to science has been as great as that of the Apollo samples.

Meteorites, however, have a clear disadvantage compared to lunar samples — a meteorite's point of origin isn't known with certainty. Fortunately, current research is enabling us to make some predictions regarding meteorite sources. In order to understand our current state of knowledge, we must review the progress of the past



A meteor from the Perseid swarm streaks toward Earth.

Scott Anderson

few centuries, beginning at a time when few astronomers believed that meteorites were of extraterrestrial origin.

Meteorite falls have long been noteworthy. The fall of "stones from heaven" is mentioned in the Bible (Joshua 10:11), as well as by ancient Chinese, Greek, and Roman writers. A meteorite fell in Ensisheim, France, in 1492 — it was placed in the town hall, and remains there today. In the mid-1700s, scientists performed the first chemical analyses of meteorites. At this time, many considered meteorites to be an atmospheric phenomenon, since thunder-like sounds often accompanied their fall. Moreover, ice fell from the sky as hailstones; therefore, it seemed logical to scientists of the day that a meteorite might form in a similar fashion from airborne dust. By the 1800s, analyses of meteorites had revealed that they contain nickel, which is relatively rare on Earth. In addition, most analyzed meteorites had compositions that were similar to each other, but markedly different from terrestrial rocks. Consequently, most scientists became convinced that meteorites were of extraterrestrial origin. Once this fact was established, astronomers began to consider the problem of finding the source of meteorites.

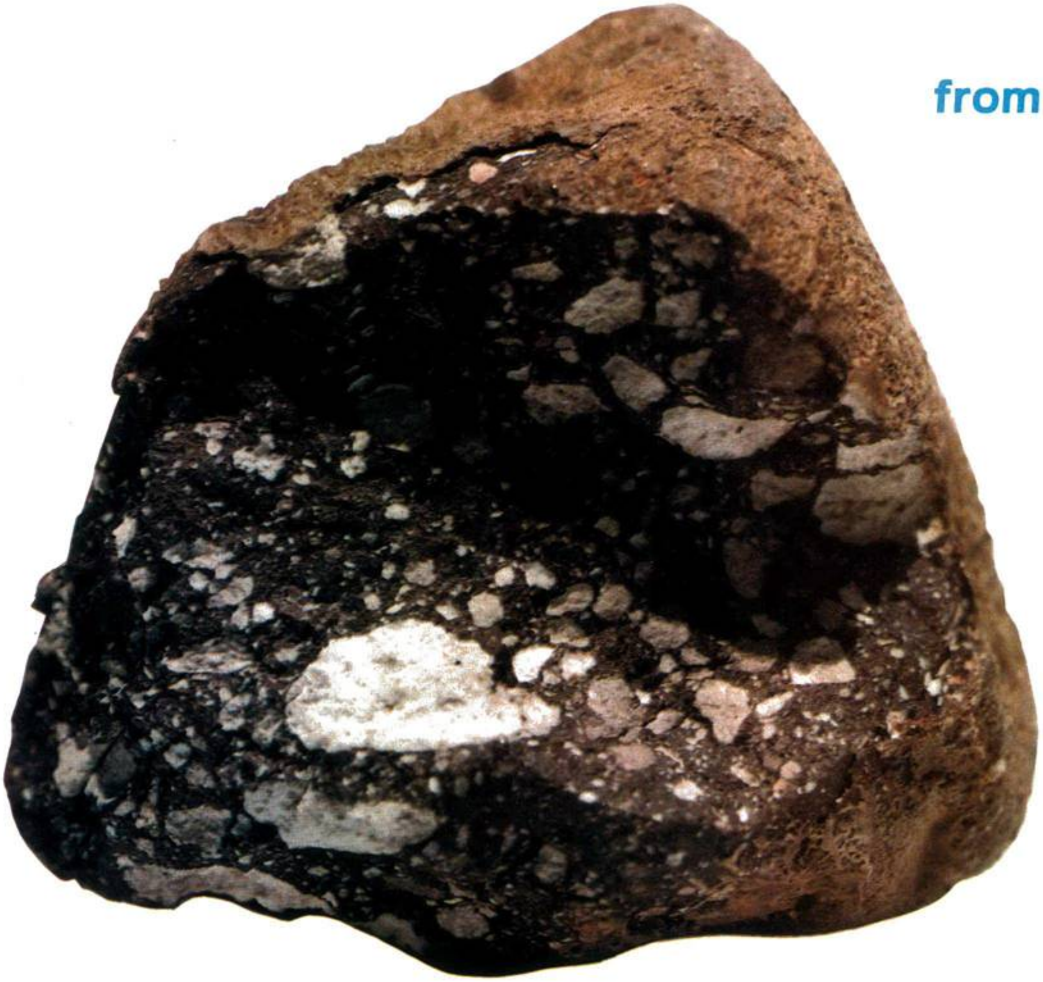
A meteorite's fall is usually accompanied by a *meteor* — a short trail of light in the sky. The behavior of meteors reveals much about meteorite sources, even though relatively few meteors yield meteorites. Meteor rates are decidely non-uniform — you can see many more after midnight than before. This is because after midnight an observer is on the leading side of the Earth as it orbits the Sun, and the Earth acts as a "meteor interceptor." A drive through a snowstorm shows a similar effect — more snowflakes hit the front windshield than the rear window. In addition to daily variations, meteor rates also vary annually. At certain times during the year, large numbers of meteors can be observed. These *meteor showers* occur because our planet's orbit around the Sun carries it through regions where intercepting objects are alternately sparse and abundant. During each shower, the meteors appear to radiate outward from a specific point in the sky, called the *radiant*. The location of the radiant marks the point in space where the orbits of the Earth and the meteor-producing objects intersect. The behavior of shower radiants is proof that meteors are extraterrestrial in origin. Observers in 1833 noted that the radiant of the Leonid appeared fixed against the stars — an unlikely circumstance if meteors and meteorites were purely terrestrial phenomena.

In the 1860s, astronomers found a relationship between meteor showers and comets. In 1862, the orbit of newly discovered Comet Swift-Tuttle was accurately determined, and in 1866, the Italian astronomer Giovanni Schiaparelli noted that the Perseid meteor shower occurs at that point in the year — August 12 — when Earth crosses Swift-Tuttle's orbit (see "Comet Swift-Tuttle and the Perseids," ASTRONOMY, August 1983). He concluded that comet debris — dust scattered along the comet's orbit — was the source of the Perseid meteors. Some meteor showers, such as the Perseids, display similar numbers of meteors every year, indicating that the debris is dispersed uniformly along the comet's orbit. Other showers are less predictable, occasionally becoming far more spectacular than usual. The most notable example is the Leonid shower, associated with Comet Tempel-Tuttle, which gives extraordinary meteor displays every 33 years. Material in the orbit of Tempel-Tuttle is not dispersed evenly. Most of it orbits in a clump near the comet, which has an orbital period of 33 years. When the 33-year orbital period of this clump of material brings it across Earth's orbit, a prolific display of Leonid meteors occurs, as was seen in 1966.

Since comets and meteors are related, one might assume that meteorites derive from cometary material. Unfortunately, several facts argue against this simple conclusion. One is the observation that meteorite falls rarely occur during showers, but tend to be associated with *sporadic meteors* — those unrelated to meteor showers. Furthermore, spectroscopic studies of comets indicate that they are mainly composed of frozen gases, with perhaps some rocky material. A comet's solid portion is usually small — only a few miles across. Consequently, an object composed of cometary material, or even an entire comet, would be unlikely to survive atmospheric passage and remain intact. Finally, chemical evidence obtained from meteorites indicates that they were formed relatively close to the Sun. And many theories of comet formation propose that they originated in the outer regions of the solar system.

With comets eliminated as the source of meteorites, one might next consider the Moon or the planets. At one time, some astronomers supposed that objects striking the Moon might break off pieces, which in turn could fall to Earth. Chemical analysis of lunar material has shown that the Moon could be the source of only a few uncommon types of meteorites, termed *eucrites* and *howardites*. These meteorites resemble a type of lunar rock named *basalt*. For the most part, though, the differences between these meteorites and lunar basalt are great enough that most researchers believe they could not have originated on the Moon. Recently, however, NASA geologists announced that one meteorite found in Antarctica almost certainly came from the Moon, and another Antarctic meteorite may have come from Mars. While we currently have no planetary samples for comparison, other planets — such as Mars — were considered unlikely to be meteorite sources, since their escape velocity is relatively high. Any process energetic enough to eject meteorites from the surface of Mars, for instance, probably would have melted them. Studies of meteorites indicate that such melting has not occurred.

Ever since the first asteroid (Ceres) was discovered in 1801, these small, mysterious objects have been suggested as likely sources for meteorites. But it wasn't until the middle of this century that scientists obtained the first definite evidence for an asteroidal origin of meteorites — the precise determination of pre-atmospheric orbits of sporadic meteorites. In order to determine the orbit of a meteor, it must be photographed simultaneously from several locations. This is frequently done for shower meteors, since it's easy to make advance preparations to study them. But the unexpected arrival of sporadic meteors makes them difficult to photograph, and simultaneous photographs of sporadics are very rare. To alleviate this paucity of information, astronomers established networks of automatic meteor cameras in North America and Europe. They have photographed several sporadic meteors from which fragments surviving atmospheric passage were recovered. These meteorites fell on Pribram, Czechoslovakia, in 1959; Lost City, Oklahoma, in 1970; and Innisfree, Alberta, in 1977. All three meteorites had *Earth-crossing orbits* — that is, the closest point of the orbit

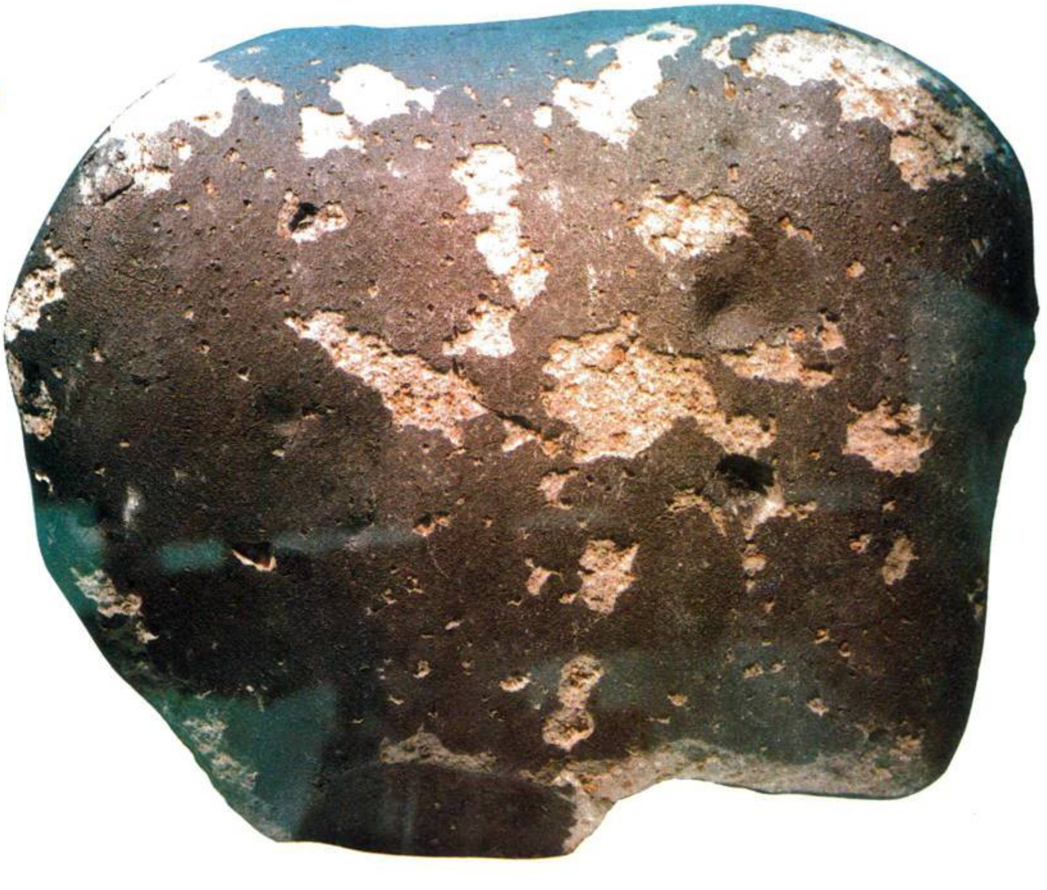


A Meteorite from the Moon. . .

Chemical analyses of this rock by NASA scientists revealed its great similarity to samples returned from the lunar highlands by the last three Apollo flights. It was found in the Allen Hills region of Antarctica.

. . . and Maybe One from Mars.

Another Antarctic meteorite shows a striking chemical similarity to the *martian* surface. Its presence, however, is a bit trickier to explain than that of its lunar cousin. Due to the higher surface gravity of Mars, any process powerful enough to eject the rock should also have destroyed it.



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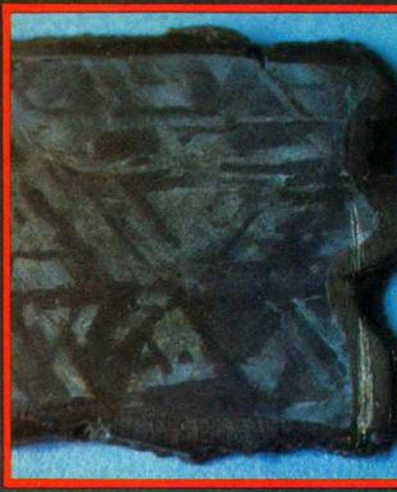
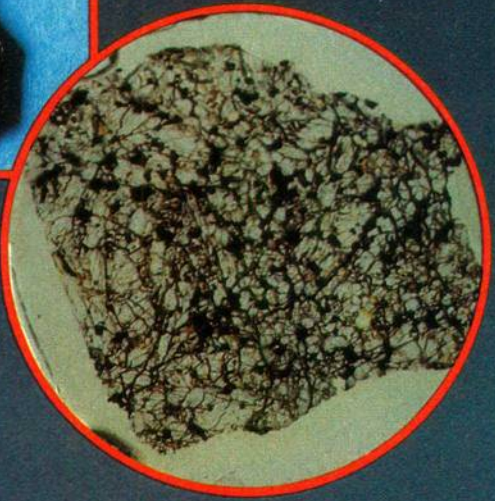
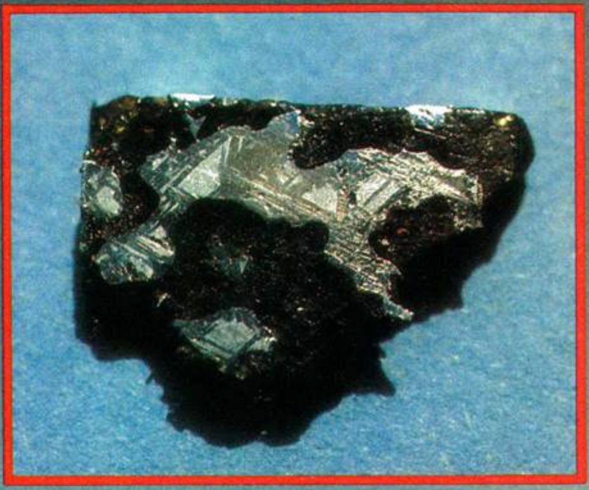


Polished section of Sacramento Mountains meteorite. Interlocking metallic crystals create the strange pattern, which occurs only in meteorites.

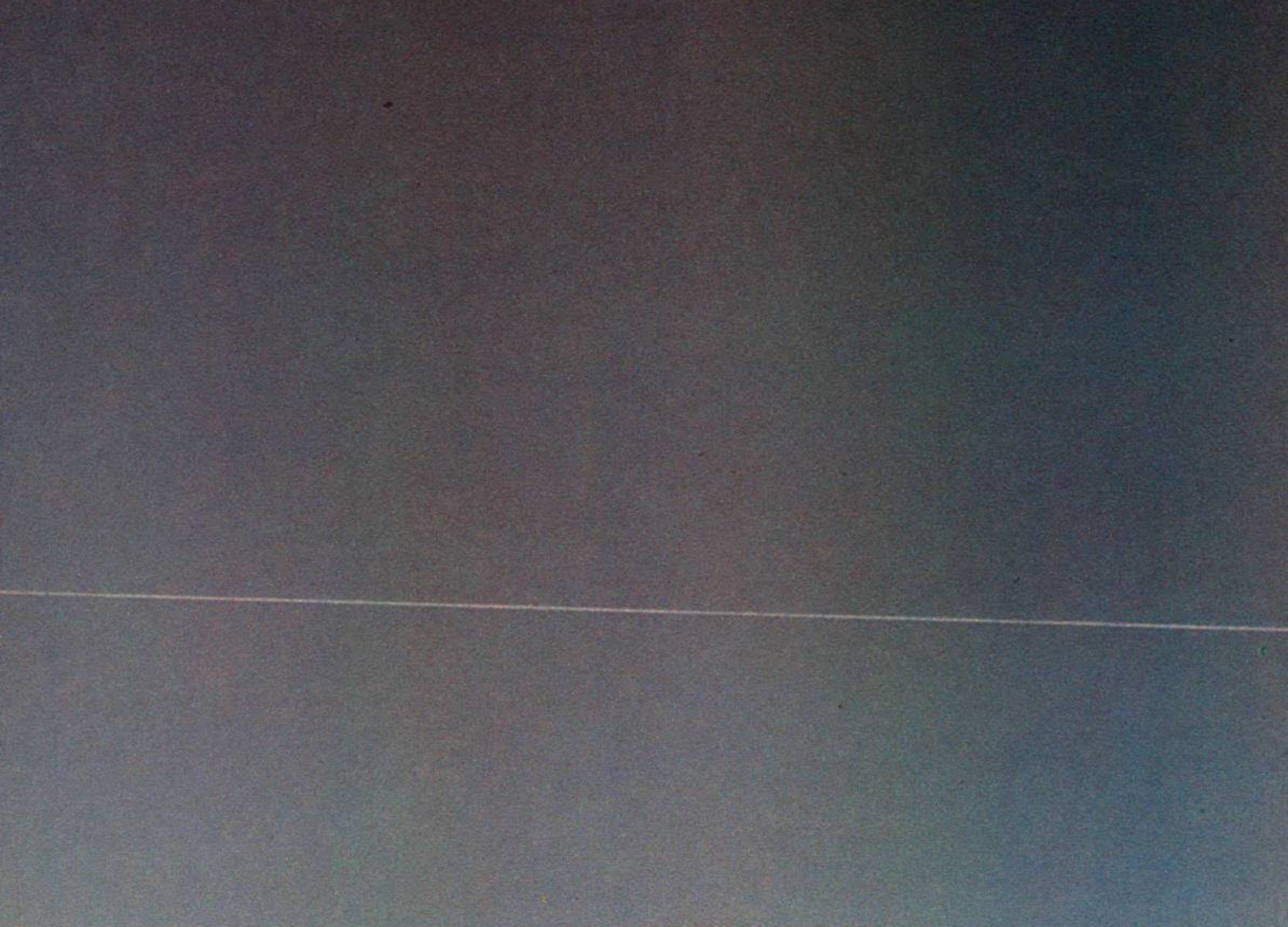


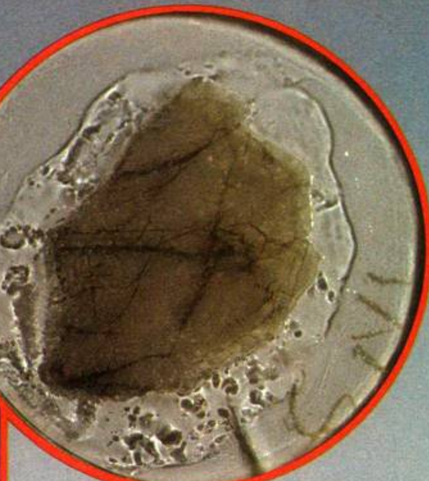
This achondrite, found in Shallowater, Texas, is almost entirely made up of the mineral enstatite.

The polished surface of a stony-iron meteorite reveals metallic (light areas) and rocky (dark brown) material.

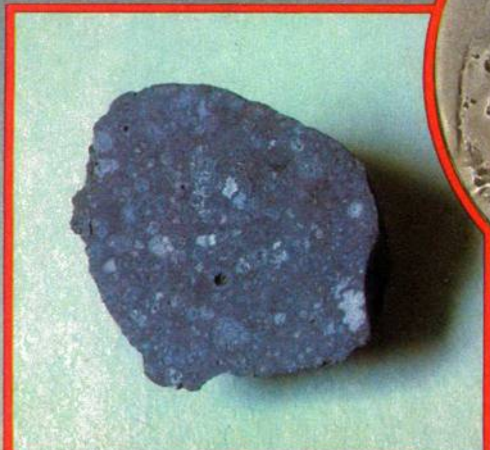


The daylight fireball of August 10, 1972, looking east from the Idaho-Montana border. Scientists estimate that the object's minimum mass was about 30 tons. But due to its extremely shallow path through the atmosphere, the object skipped back into space. Photo by Lanny Ream.

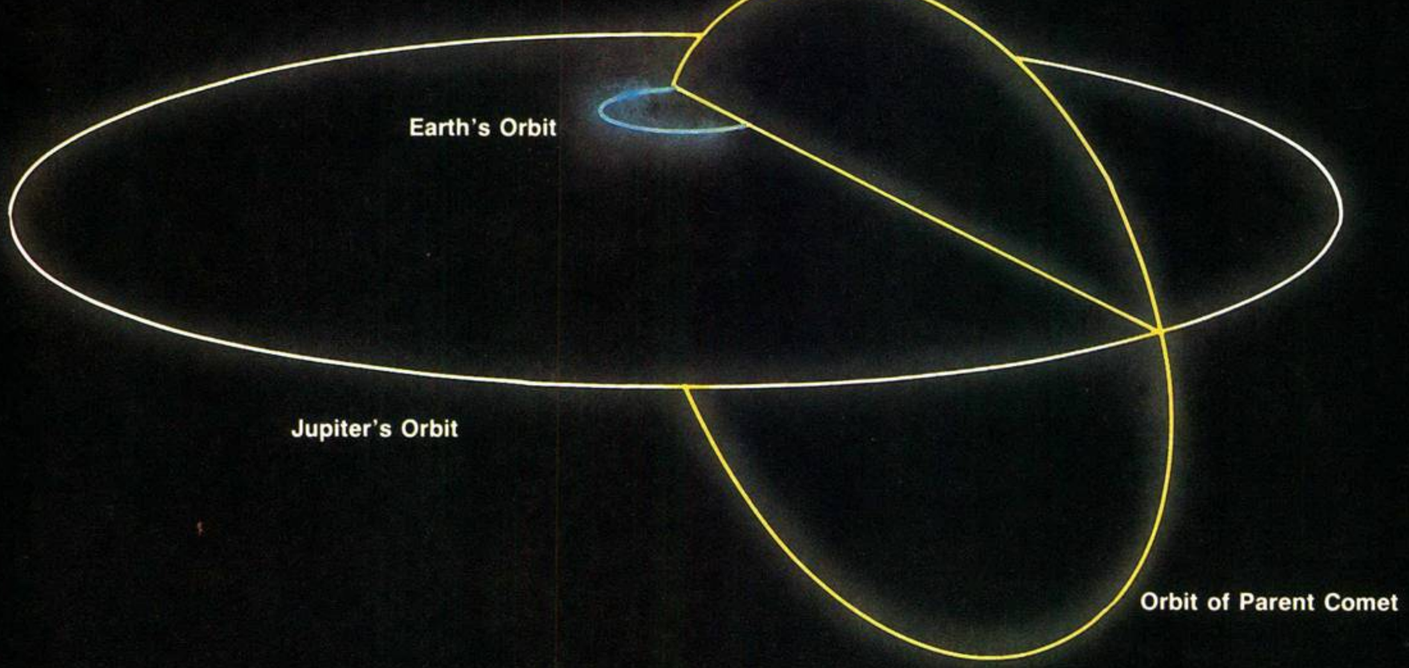




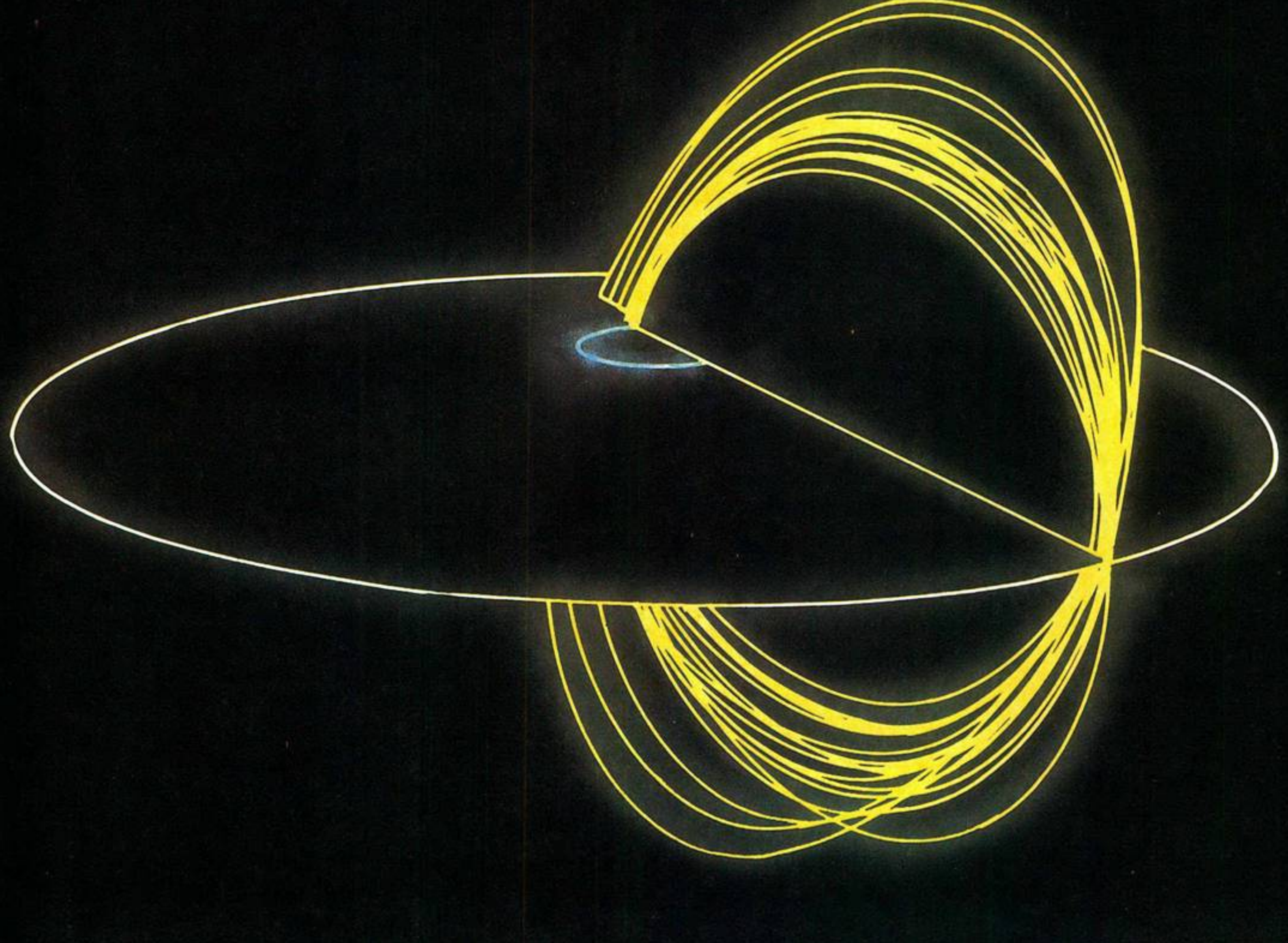
Half-inch section from a stony-iron meteorite that fell on Tunisia in 1931.



Fragment from Allende shows chondrules, the spherical bodies for which chondrites are named.


Earth's Orbit
Jupiter's Orbit
Orbit of Parent Comet

As a comet orbits the Sun, it leaves behind a trail of dusty debris. Gravitational interactions with the Sun, Earth, and Jupiter alter the orbits of these meteoroids over a few hundred years. When Earth runs into the streams of comet debris, the result is a meteor shower — in this case, the Quadrantid.



to the Sun was inside the Earth's orbit, and the farthest point beyond it. The *aphelion* — farthest point from the Sun — of all three orbits was within the asteroid belt. Some asteroids, known as *Apollo asteroids,* have Earth-crossing orbits and could possibly strike the Earth in the future. Most astronomers now believe that collisions between asteroids produce small fragments, which are knocked into new, Earth-crossing orbits. Consequently, the meteorites that have fallen to Earth are samples of asteroid material.

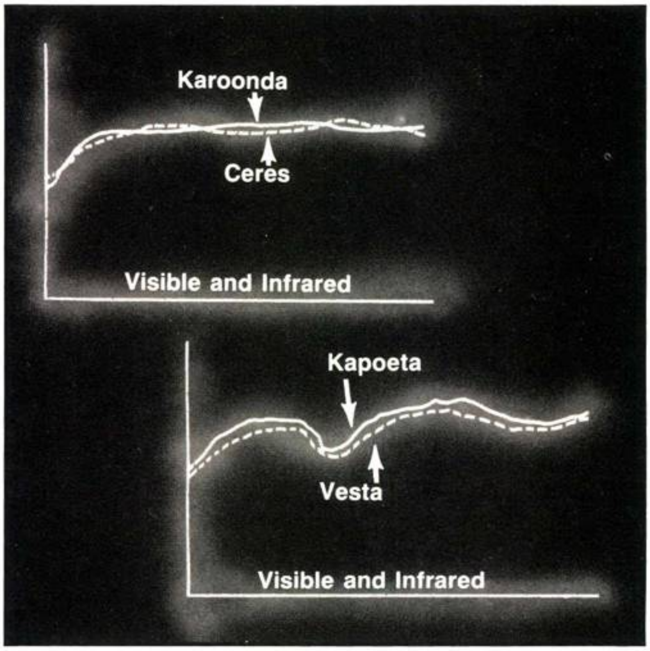
With meteorites believed to originate in the asteroid belt, recent research has made comparisons between specific meteorites and specific asteroids, with the goal of matching a meteorite to an asteroid from which it might have originated. This process is complicated by the presence of a wide diversity of meteorite types. The majority of meteorites are *stony*, resembling to some extent terrestrial rocks. Stony meteorites are subdivided into two groups: *Chondrites* contain small spherical bodies called *chondrules*, which formed early in the history of the solar system. The Allende meteorite is a chondrite. *Achondrites*, which lack chondrules, include the previously mentioned eucrites and howardites. *Iron* meteorites are metallic alloys of nickel and iron, and *stony-iron* meteorites are mixtures of both rocky and metallic material.

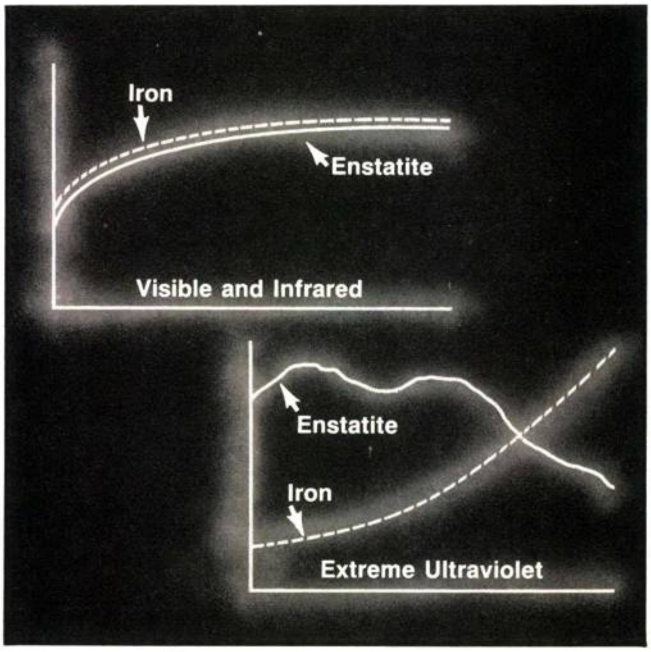
The process of matching meteorites and asteroids involves one of astronomy's most powerful techniques, spectroscopy — the analysis of light received from an object. Most astronomers using spectroscopy study objects that emit their own light, but planetary researchers study the light that objects, such as asteroids, reflect from the Sun. Most objects reflect different amounts of light of different colors. An apple, for example, appears red because its skin absorbs blue and green light, and reflects red light. Chemicals in the apple's skin absorb light of a particular wavelength — a measure of light that defines it more precisely than its color. Light of longer wavelengths than visible light is infrared; that of shorter wavelength is ultraviolet. Knowing which wavelengths of light are absorbed by specific substances, whether they are in an apple's skin or an asteroid, allows astronomers to determine an object's composition spectroscopically.

By using spectroscopy, we've obtained some good matches between meteorites and asteroids. First, the spectra of meteorite samples of various types are measured in the laboratory, usually using visible and infrared light. The different types of meteorites generally exhibit specific spectral features that enable us to distinguish them. In addition, astronomers make visible and infrared spectra of asteroids using telescopes. Asteroids have been classified into about six groups, each one containing those with similar spectra. After obtaining spectra of both meteorites and asteroids, planetary geologists made careful comparisons and learned that some spectra were nearly identical. For example, the spectrum of Vesta, the brightest asteroid, is nearly identical to that of Kapoeta, a basaltic achondrite (see "Vesta: A World of Its Own," ASTRONOMY, February 1983). The spectra of Ceres and Pallas, the first two asteroids discovered, are similar to that of Karoonda, a chondrite resembling Allende. While these matches do not *prove* a meteorite's origin — Kapoeta was not necessarily once part of Vesta — they suggest that the two objects formed under similar conditions and that possibly both were once part of a larger body.

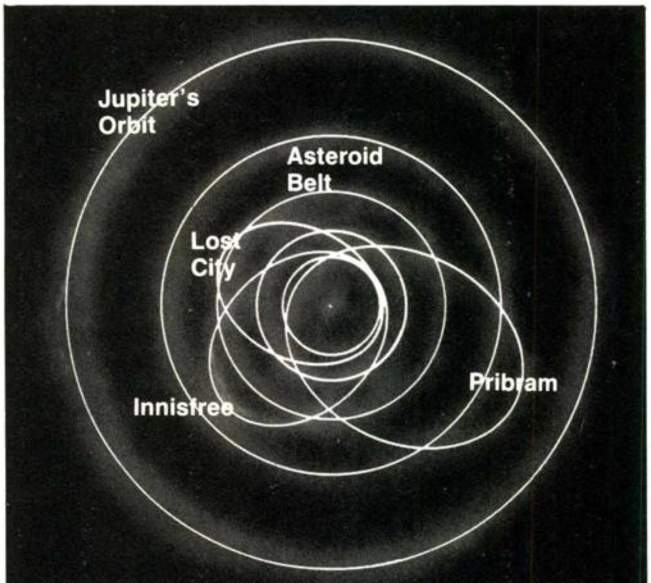
Not all meteorites are distinguishable using visible and

Planetary geologists can now compare the spectra of specific meteorites with the spectra of specific asteroids. Below: Plots of amount of light reflected as a function of wavelength in the visible and infrared part of the spectrum. Solid lines represent meteorite and broken lines represent asteroid. Bottom: Scientists can distinguish iron meteorites from stony meteorites made of enstatite by using ultraviolet light.





infrared spectra. For example, stony meteorites composed entirely of the mineral *enstatite* have spectra very similar to those of iron meteorites. Fortunately, spectra of these two types of meteorites are easily distinguished in the extreme ultraviolet portion of the spectrum. Unfortunately, this short-wavelength light will not pass through atmospheric gases, so astronomers using Earth-based telescopes can not obtain extreme ultraviolet spectra of asteroids. Later in this decade, when the Shuttle places the Space Telescope into orbit, planetary geologists will be able to measure the extreme ultraviolet spectra of asteroids. We hope that this technique will allow us to make more asteroid-meteorite matches and will also give additional evidence to verify matches made using visible and infrared spectra.



Orbits of three meteorites before they entered Earth's atmosphere.

The evidence pointing to an asteroidal origin of meteorites is very strong. Most planetary geologists believe that the asteroids formed as a number of small bodies, rather than as a single large body. Some of these small bodies have remained virtually unchanged since their formation, and meteorites derived from them, such as Allende, contain valuable evidence about the solar system's formation. Others were large enough so that heat and pressure effects within them caused *differentiation* — separation into layers, each of a different composition. When these larger bodies collided and broke apart, samples of the separate layers produced a variety of meteorite types.

While a sporadic meteor may appear to be only a brief flash of light in the sky, it is the last event in the life of an object with a long and complex history. As a result of the combined work of astronomers and geologists, the sources of these objects and the details of their history are finally coming to light.

Scott Anderson

Jeffrey K. Wagner teaches geology and astronomy at Firelands College in Huron, Ohio. His doctoral research was on extreme ultraviolet spectroscopy of meteorites.

Chondrites and the Early Solar System

by Alan E. Rubin

Perseid photo
by Deborah Kutner

Meteorites are our most abundant source of extraterrestrial material. For almost two centuries, studying them has broadened our understanding of the nature, origin, and evolution of the solar system. We now know that most meteorites formed about 4.6 billion years ago — before all presently existing terrestrial rocks and most lunar rocks. Rocks that formed on Earth during our planet's first 700 million years have been destroyed by volcanic eruptions, floods, colliding continental and oceanic plates, burial by younger sediments, erosion, and other processes. The violent early history of the Moon, involving deep crustal melting, volcanic eruptions, and intense meteorite bombardment, also caused the destruction of most lunar rocks older than about four billion years. Meteorites alone provide us with sufficiently ancient material to begin to unravel the complex history of the early solar nebula, the gaseous cloud from which the Sun and planets coalesced.

There are three major classes: *irons*, metallic nickel-iron meteorites with minor amounts of non-metallic minerals, *stony-irons*, consisting of about half metallic nickel-iron and half silicates, and *stones*, silicate bodies with minor amounts of nickel-iron and iron sulfide. Stony meteorites are by far the most common type to strike Earth — a reflection of their greater abundance in interplanetary space.

The two main groups of stony meteorites are the *chondrites*, which contain millimeter-sized spheroidal objects called chondrules (after the Greek word *chondros*, for grain of seed), and the *achondrites*, which lack these objects. Each group of stony meteorites is, in turn, subdivided into several different categories. Although each subgroup contains fascinating objects that mark events from different epochs of solar system history, the ordinary chondrites and the chondrules they contain command the attention of most meteorite researchers.

Ordinary chondrites exist in great numbers — they constitute more than 80 percent of all observed meteorite falls. The three main groups of these meteorites (which originated in three separate parent bodies) are the H (high iron), L (low iron), and LL (low iron, low metal) chondrites — named after their compositional abundances of total iron (metallic nickel-iron and iron embedded in sulfides and silicates).

Some ordinary chondrites in each group have chondrules with sharp outlines, while others have apparently recrystallized so that a few chondrules blend with silicate grains. Mineral compositions of the recrystallized chondrites are uniform, whereas the unrecrystallized chondrites display a large variation in mineral composition. Most scientists believe that recrystallized meteorites experienced higher temperatures, which erased chondrule textures and caused the silicates to become uniform. Individual chondrites have a type number (3, 4, 5, or 6) that indicates the meteorite's degree of recrystallization.

H3, L3, and LL3 chondrites, having been subject to little or no metamorphism, have the widest variations in mineral compositions and the least amount of recrystallization. H6, L6, and LL6 meteorites, on the other hand, show the most recrystallization. Because type 3 chondrites are the most pristine representatives of ordinary chondritic material, studying them provides detailed information on the solar nebula.

Perhaps the most exciting research concerning the type 3 ordinary chondrites is on the nature and origin of their chondrules. Chondrules are generally 0.5 to 2.5 millimeters in diameter, composed of the iron- and magnesium-rich silicate minerals olivine and pyroxene. They also contain minor amounts of glass between these silicate grains. Chondrules are virtually unknown in terrestrial and lunar rocks, but comprise up to 70 percent of some ordinary chondrites. Although there is a great variety of textures in chondrules, all can be classified into a few types. Coarse-grained chondrules, consisting of large grains of olivine and pyroxene surrounded by glass, account for about 85 percent of the chondrules in type 3 chondrites. Barred olivine chondrules are a special variety of coarse-grained chondrule; they contain elongated, parallel-oriented olivine crystals. Fine-grained chondrules include radial pyroxene types; these are very distinctive, consisting of elongated grains of pyroxene that appear to radiate from the chondrule's perimeter like a Japanese fan.

The mineralogy, composition, and spheroidal shape of chondrules tell us that they are crystallized droplets of silicate. Many ideas on the origin of chondrules have been proposed over the years, ranging from droplets of a fiery rain to volcanic ash. Large compositional variations in chondrules in type 3 ordinary chondrites indicate that the chondrules formed by the melting of solid materials. One mechanism for such melting is a lightning discharge in the solar nebula; as dust grains accumulated into a narrow central plane, the surrounding gas would have rotated at different velocities, creating a buildup of static charge. It is quite possible that lightning flashed frequently along this plane, melting and remelting solid materials, forming them into chondrules.

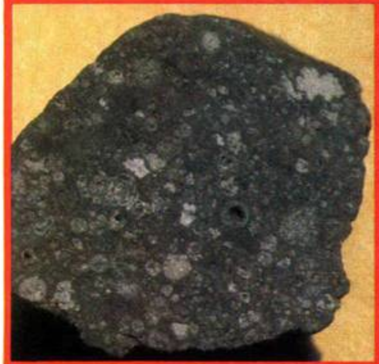
One of the major components in type 3 chondrites — besides chondrules — is a fine-grained silicate material. It forms rims on many chondrules and also appears as millimeter-sized fragments. Such material also occurs as lumps *inside* a number of different kinds of chondrules, indicating that silicate was already present in the solar nebula at the time chondrules formed. Compositional similarities between silicate and chondrules suggest that chondrules formed in the nebula by melting fragments of this material.

After chondrules formed, they agglomerated with unmelted silicate and grains of iron sulfide and metallic nickel-iron to form chondrites. As accretion continued, the growing chondrites became hot from the decay of aluminimum-26 (^{26}Al), a short-lived radioactive isotope present in the nebula. Peak temperatures may have been reached in small bodies called planetesimals (10 to 20 kilometers in diameter) which subsequently accreted into large (300 km to 400 km) bodies. These large bodies then cooled as single objects. The planetesimals that accreted earliest contained the most ^{26}Al and reached the highest temperatures. Such planetesimals contained recrystallized type 6 chondritic material. Other planetesimals, accreting later, contained less ^{26}Al, experienced lower temperatures, and contained less recrystallized type 6 material and more type 3 and 4 material.

As the large bodies formed from the planetesimals, different metamorphic types were mixed together. Some type 6 planetesimals wound up near the center of the large bodies and cooled slowly; others, nearer the surface, cooled more rapidly. There is no correlation between a chondrite's rate of cooling and its metamorphic type.

A number of observations indicate that asteroids are

Types of Stony Meteorites

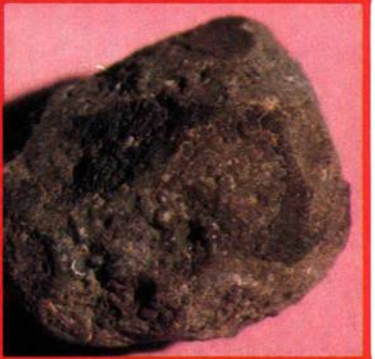


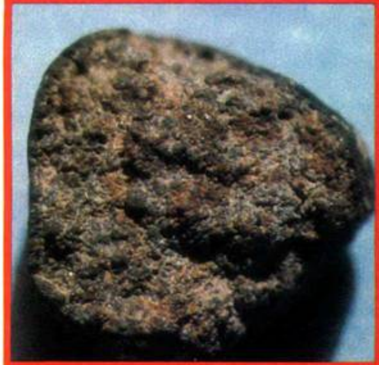
Chondrites

are the commonest type of meteorite and are similar in composition to the early solar system. They contain chondrules, millimeter-sized spherical bodies that probably originated as molten droplets of matter in the solar nebula. About 95% of all meteorite falls are stony meteorites (although they are relatively hard to find because, unlike iron meteorites, they look like Earth rocks) of which 87% are chondrites. Thus four of every five meteorites are either a carbonaceous, enstatite, or ordinary chondrite.

Carbonaceous Chondrites

are the most primitive chondrites, having undergone the least amount of mixing and remelting since the formation of the solar system. There are four subclasses of carbonaceous chondrites — CI, CN, CO, and CV — which differ slightly in composition and chondrule size. The CI class, accounting for 1.4% of stony meteorites, shows a primitive claylike silicate structure and olivine, from deteriorated chondrules. The CI chondrites are rich in water, containing as much as 20% H_2O. CN types make up for 3.9% of stony falls; they are composed of a claylike matrix material with about 5% water. CO types — about 1.7% of stony falls — are composed of tiny chondrules in a silicate, while CV types, making up 2.2% of all falls, show large chondrules and a fine grain silicate structure. Altogether, the carbonaceous chondrites make up 9.2% of all stony falls.



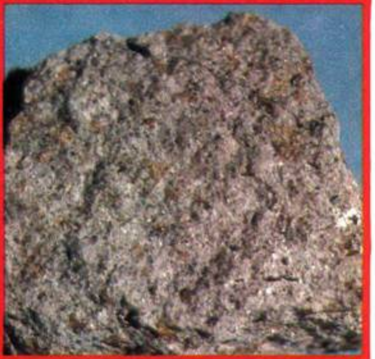


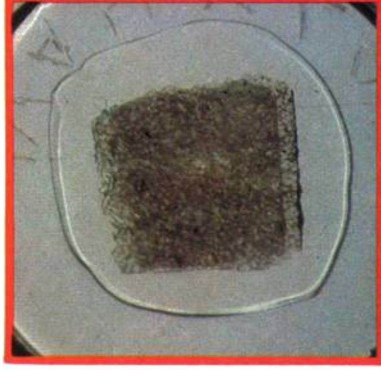
Enstatite Chondrites

are relatively rare meteorites, accounting for only 3.1% of all stony meteorite falls. Thus little is known about them, except that they are divided into two broad categories — EH and EL — denoting high and low iron content. These meteorites contain large amounts of metallic iron along with their chondrules, and show different compositions than the carbonaceous meteorites. The high iron subclass shows up at 1.4% of all stony falls, while the low iron type is somewhat more abundant at 1.7%.

Ordinary Chondrites

are by far the commonest type of stony meteorite, responsible for 87.7% of the falls. They are divided into two classes, HL and LL, denoting high and low levels of metallic iron nickel. The high iron types account for 32.0% of all stony meteorites, while the low iron types make up 55.7% of stony falls. These have large chondrules and, apart from their iron nickel content, slightly different compositions than the enstatite and carbonaceous types.

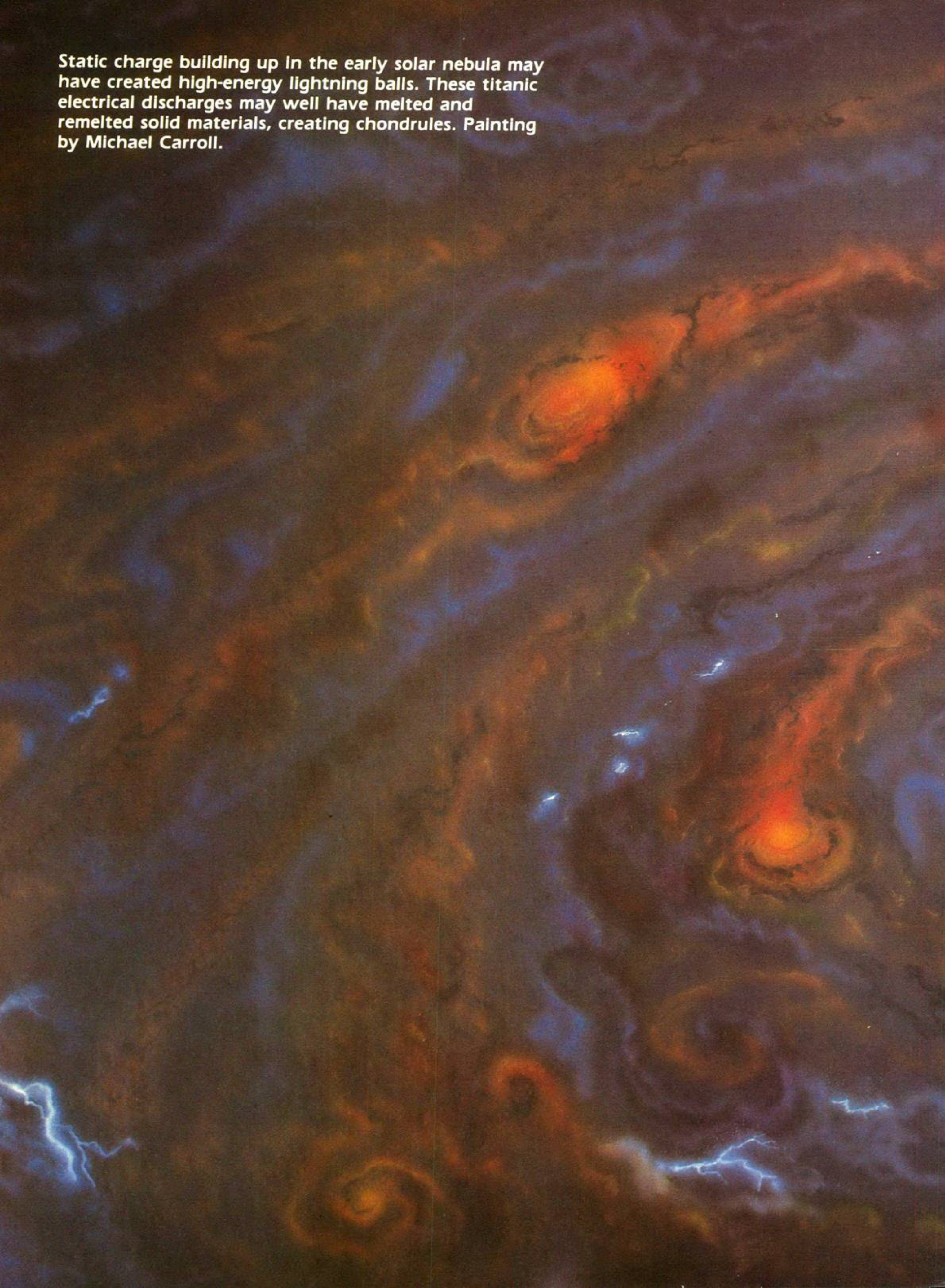




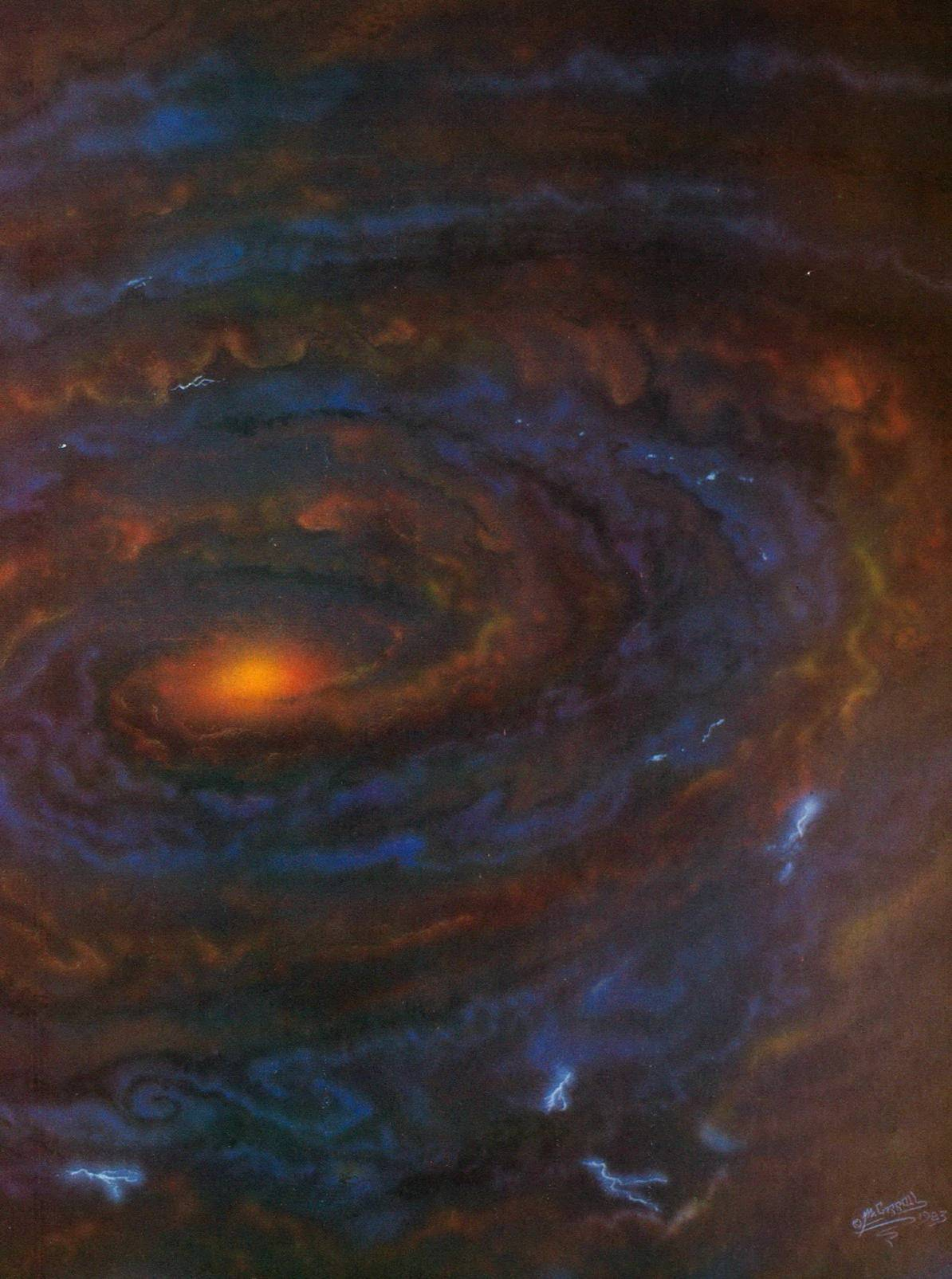
Achondrites

lack chondrules and make up the rest of the stony meteorites. They are divided into nine groups: *aubrites*, like the enstatites but lacking chondrules; *diogenites*, iron-rich achondrites; *chassignites*, olivine-rich meteorites; *ureilites*, carbon-rich meteorites sometimes accompanied by diamonds; *angrites*, calcium-rich meteorites; *nakhlites*, made up of olivine and other compounds; *euchrites*, composed of basalts; *howardites*, mixes of euchrites and diogenites; and *shergottites*, unusual complex meteorites. Most meteorites are about 4.55 billion years old, but three of these types are much younger; the chassignites, nakhlites, and shergottites are only 1.3 billion years old, leading some researchers to believe that they are from Mars.

Photos by Jeffrey K. Wagner



Static charge building up in the early solar nebula may have created high-energy lightning balls. These titanic electrical discharges may well have melted and remelted solid materials, creating chondrules. Painting by Michael Carroll.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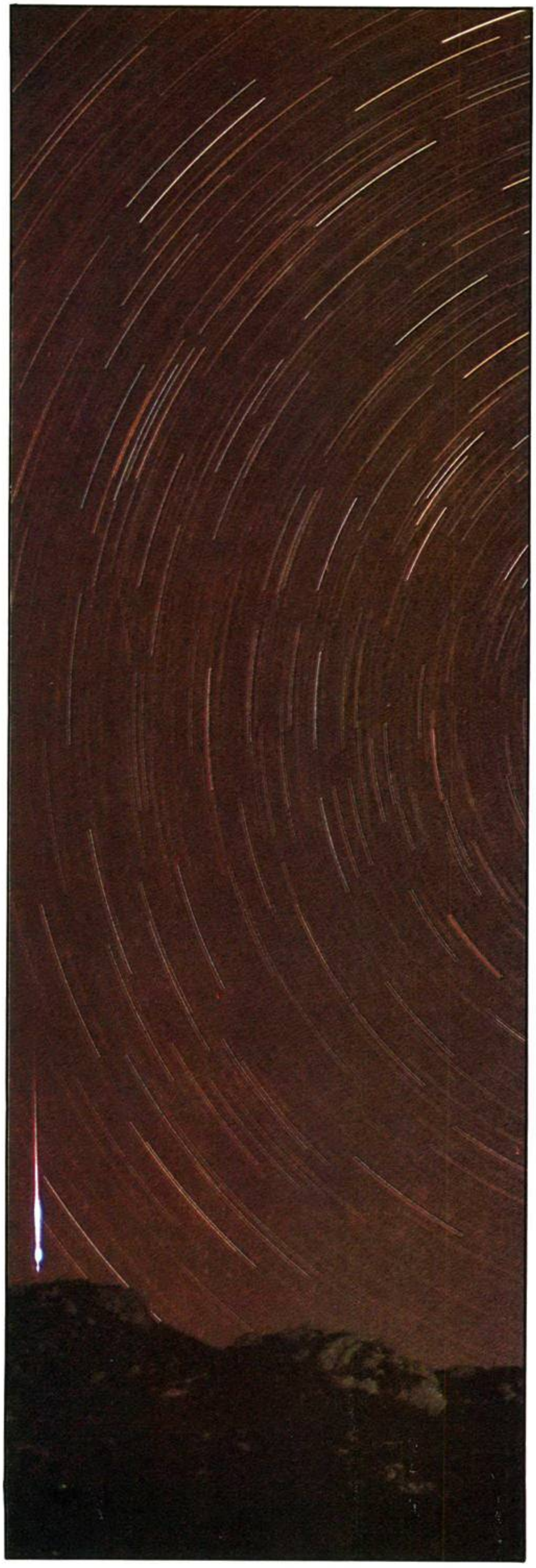

Martin Anderson

the parent bodies of ordinary chondrites. First, most ordinary chondrites cooled very slowly, at rates of 1° to 100° C per million years, indicating that the chondrites were buried beneath 5 km to 150 km of insulating rock on bodies at least 300 km in diameter — the size of some of the larger asteroids. Second, studies of solar-wind gases trapped in stony meteorites show that gas implantation occurred in the vicinity of the "asteroid belt," the zone between about 2.3 and 3.3 astronomical units (AU) from the Sun in which almost 90 percent of the asteroids reside. Third, spectrophotometry of S-type asteroids, abundant in the inner portion of the asteroid belt, reveals apparent compositional similarities to ordinary chondrites. And fourth, asteroidal orbits for three ordinary chondrites have been determined from photographic observations made as the meteorites penetrated the Earth's atmosphere.

When meteorite projectiles strike the surface of an asteroid at about 5 km per second, the average relative velocity in the asteroid belt, so much energy is released that some material is ejected into space. Some of this material eventually intersects the Earth's orbit. Meteoroids in Earth-crossing orbits — Apollo objects — have typical lifetimes of 10 million years before they strike either the Earth or Venus or are ejected from the solar system by close planetary encounters. A continual flow of these objects is maintained by burnt-out comet nuclei and fragmentation of main belt asteroids. The types of meteorites reaching the Earth are dictated by the composition of fragmented asteroids that replenish the Apollo objects. Thus, the abundances of different kinds of meteorites bombarding the Earth in the past were probably somewhat different from those that strike the Earth today.

Since 1969, thousands of meteorite fragments, representing several hundred falls, have been recovered in Antarctica, where flowing ice has concentrated meteorites near protruding mountain peaks. Most Antarctic meteorites fell to Earth 30,000 to 400,000 years ago and indeed represent a somewhat different mixture of meteorite types than current falls. Many type 3 ordinary chondrites, including several unique specimens, have already been recovered.

A few ordinary chondrites contain fragments of new kinds of meteorites, not known to occur as individual meteorites. The host chondrites came from asteroid surfaces, which served as collection areas for projectiles, just as the surface of the Earth collects impacting meteorites. However, almost all of the individual meteorites in our collection fell to Earth within the past million years, whereas those ordinary chondrites derived from asteroid surfaces may have incorporated projectiles from a much earlier period, perhaps several *billion* years ago. In addition, whereas the Earth only receives projectiles orbiting the Sun at a distance of 1 AU, asteroids are struck by objects orbiting the Sun near 3 AU — almost 300 million km farther away.

The rain of chondritic meteorites on the inner planets over the last few billion years is but one aspect of the geological evolution of the solar system. Accretion of chondritic material 1 AU from the Sun formed the Earth in the first place. The continued collecting of such material on Earth has enabled meteorite researchers to begin to understand the formative years of the solar system.

Alan E. Rubin received his Ph.D. in geology from the University of New Mexico in 1982. He is a meteorite reseacher at UCLA in Los Angeles.

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My First Telescope

The dim beginnings of my interest in astronomy are lost in distant antiquity — in truth, far more distant than I would like. But even before its prominence in my life, it shared adolescent enthusiasm with many other "secondary education" endeavors. Among them were fish breeding, history, chemistry, poetry and story writing, and fossil collecting. As a budding naturalist, I kept and studied lizards, tortoises, frogs and other amphibia, ant colonies, and a guinea pig. I even found time to go to school. However, from this confused childhood, the single memory that stays with me is the acquisition of my very first telescope. The capacity for amnesia being my prime forte, I can only surmise that the event remains clear because it occurred whilst I was on a particularly sunny holiday.

It was the summer of 1968, which puts me at 15 years old at the time. Dad had transported Mum, my two sisters, and me to the Channel Island of Jersey off the coast of France for two blissful weeks of freedom. We stayed in a modest hotel that resembled a large country house, called romantically "Chateau Valeuse." It nestled beneath the ramparts of a rugged cliff — so closely, in fact, that the lower branches of trees clinging to the steep slope almost touched the hotel roof. This did not daunt the proprietor's plans for a swimming pool beneath the leaves.

Once unpacked, and having satisfied ourselves that essentials like wash basins and loo flushes worked adequately, we soon settled down into set routines. Activities within the hotel were mainly restricted to our breakfast and evening meals; for the latter we had to dress up in our Sunday best. I detested doing this on holiday, a period I thought of as being strictly laissez-faire. But of course during the day we ventured outside to sample the delights of the desert island sunshine.

Leaving the grandiose porch of the hotel for safari-like journeys of discovery, our walks could take one of three main routes. The trips down to the seaside, or "the front," were the best, as far as I was concerned. The beach — visible from our hotel rooms through at least four gaps in the intervening buildings — was located at the outlet of a small river, which formed a long sinuous rocky ribbon of sparkling water that fought its way across the thirsty sand to the sea's edge. Each stone and boulder was the focal point of a rock-pool: sometimes clear and tepid; sometimes a swirling circular current that tugged at the legs. But each and every one had to be meticulously searched and examined for the forms of life that called it home. As I spent most of my time doubled up, peering with shaded eyes into the water, it was always my back that was sunburnt first.

Or it might be a good-stretch-o'-the-legs along the coastal pathways, winding their erratic trail around the wind-blown cliff tops where the seagulls played, skirting precipitous drops that kept my mother on tenterhooks. For me, these trips were adventurous nature trails. I would fight my way through the heather-strangled undergrowth, upturning every rock I could lift in my enthusiastic search for creepy-crawlies. The most treasured finds were slow worms. These creatures are not the slimy nematodes you dig up in the garden, but light brown legless lizards reminiscent of small snakes.

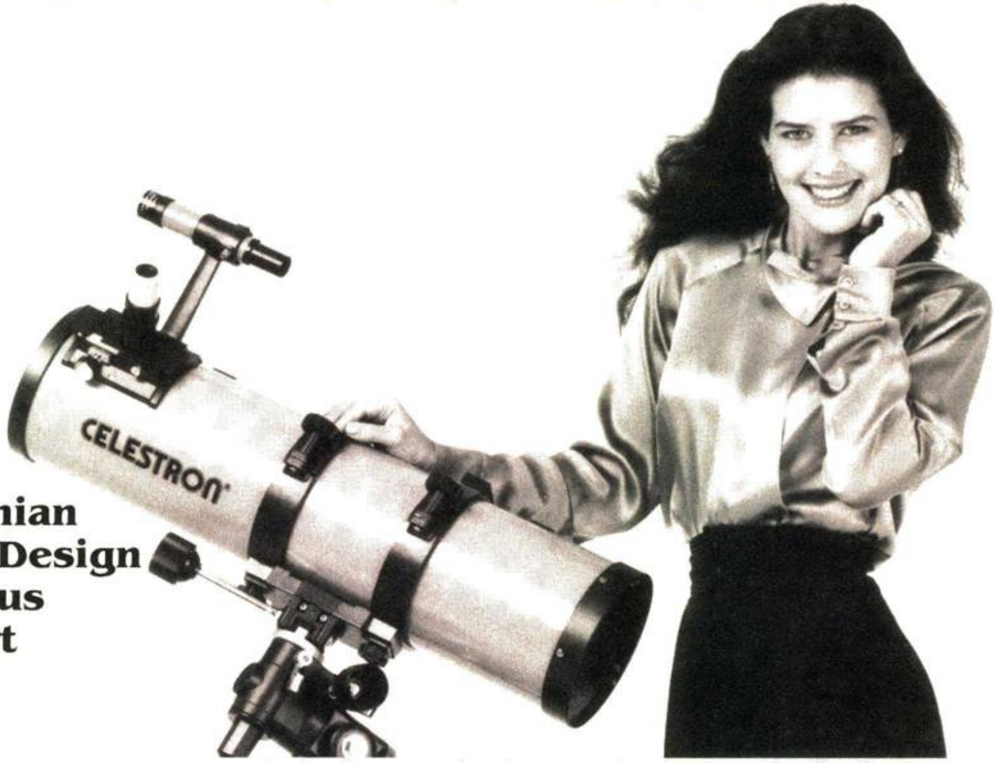
One such creature I succeeded in capturing on this holiday was kept in a large matchbox, hidden cozily in the scrubland behind the hotel. I assumed, correctly I believe, that my pet would have been an unwelcome guest inside the hotel. Every day I would surreptitiously visit my captive to feed it on the abundant insect life in the area. Unfortunately, through my mishandling, he saw fit to divest himself of his tail and it fell to the ground, where it flipped and flopped of its own accord for a few minutes. I felt a deep sense of shame, since his previously sleek and whip-like appearance had been spoiled, but I knew that a new tail would grow from the fresh pink stump. It was one of the saddest moments of my life when, on the day we left for home, I visited the matchbox for the last time and gave him back his freedom.

The third trail was the one we took to go shopping. A small tarmac path crawled its way up the incline behind us through a cool wooded park, on a long journey to the summit where a bustling shopping center lay. These trudging excursions, a necessary evil, were dreaded by my father and me. There was only one consolation — the opportunity to spend some of my holiday money, hard-earned by the labor of car cleaning.

The holiday was still young as we staggered up the hill for about the third time that week. Arriving at the top was always a shock to our systems, suddenly breaking from the pleasant leafy pathway into the busy dusty panic of commerce, usually in various states of breathless and sweaty exhaustion. I had yet to make a significant purchase with my savings, a princely sum that amounted to a little over eight pounds. The shopping trip proceeded in the normal fashion. Methodically, in blind obedience, we followed Mum in caravan-like form from one essential purchase to another: suntan oil for the Sun, calamine lotion because of it, bread for sandwiches, postcards for people who had sent us one the previous year, daily out-of-date papers and magazines — through an unending list of holiday paraphernalia.

Almost asleep from boredom during this particularly grueling marathon, I stood alone outside a large chemist's whilst the rest of the family inside

NEWTON WOULD BE ASTOUNDED



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CELESTRON INTERNATIONAL, P.O. Box 3578 B11, 2835 Columbia St., Torrance, CA 90503 (213) 328-9560 stocked up on vitamin pills and aspirin. In an effort to stay awake in the stifling heat, I subjected the window before me to close scrutiny. Shelves placed close to the large expanse of plate glass groaned under the weight of bottles, packets, and home-care articles. There seemed no logical order to their distribution. Towels and flannels shared room with electrical shaving equipment, boat salts vied with suntan creams, beach sandals were sprinkled with cosmetics. Then I saw it. Nestled between three small pairs of binoculars sat a telescope.

Before that moment, I must confess that buying a telescope had never entered my mind, but only seconds later I had abandoned my sentry duty on the pavement and was inside asking an assistant for a better look. My excitement must have been written across my face — I detected a suppressed smile from the assistant as he placed the scope before me on the counter. My eyes caressed the shiny white enamel tube, the short "elbow" tripod, the gleaming 40mm lens, and the ratchet eyepiece. The eyepiece mechanism particularly interested me; depending on the position of the eyepiece tube, the instrument's magnification could be varied from 25x to a whopping 50x. By the time the rest of the family had noticed my presence in the shop and walked over to find out what I was up to, I had already decided that I must have it. It really thrilled me to discover that the telescope would cost 7 pounds, 10 shillings — it was just within my grasp.

My parents were not as happy about it as I. They advised me that such a major purchase should not be made on the spur of the moment, adding that, so early in the holiday, it would leave me with very little money to spend on other things. They forced me to promise to wait one day, just to be sure that I really wanted it. How little they knew me, for a flame of interest had ignited within me that was to last for the rest of my life.

A day that dragged its heels was followed by a sleepless night. I was constantly tortured by the fear that the telescope would be missing from its place in the window on our next shopping trip up the hill. Moonlight shone through the window, and I imagined the wonders of space that would soon open up to me — the Moon, the planets, the stars. My heart soared at the prospect, then sank with the terror of losing the telescope. My hope rose and fell like the rolling sea I could hear through the door.

The day dawned, and I woke bleary-eyed from a fitful sleep. But the cobwebs were swept from my mind as I remembered the telescope. I thought hard to visualize it as I had last seen it. I was up and dressed far too early for breakfast, so I ventured out into the cool morning air to feed my slow worm. He was lethargic from the cold of night, but soon perked up as the rays of the sun warmed us both. I caught a grasshopper, which disappeared soundlessly into his pale mouth. His forked tongue licked his horny gums with an almost human relish, the eyes blinking at me with the expectation of more. After allowing him some exercise, I returned him to his matchbox. I considered rushing up the hill, there and then, to see if the telescope was there, but breakfast was ready. I had to wait.

My parents made their usual slow, methodical way up the shadowed path to the shopping center. I went ahead in spasms, occasionally hovering, torn between eagerness to see what I now considered to be my telescope, and the necessity for them to catch up to me. We emerged, as always, into the arena of blindingly bright concrete and rushing people. I made a beeline for the chemist's.

I could not believe it; I hardly trusted my eyes. It was there! But even now, in the next few seconds, it could disappear from view. There were people in the shop. One of them could be asking for my telescope at that very moment. Worried and impatient, I looked down the road for the rest of the family. It took an age for them to reach me. "It's still there, then," said Dad rather unnecessarily. We entered the shop as one body. I was excited and nervous. My hands were sweaty.

The assistant saw us enter, and by the time we reached him he had placed the telescope on the counter for another examination. I went through the motions with lightning speed, for I wanted to possess it as soon as possible. Incredibly, there was still discussion of my genuine interest in the telescope. Then, almost in a dream, I heard myself saying, "Thank you, yes, I'll take it." As custodian of all our holiday funds, Mum counted out and handed me the money which I passed on to the assistant with a trembling hand. It was the most I had ever spent in one go. I felt a rapid thumping in my chest as I watched my telescope being carefully packed away in cardboard and polystyrene.

The rest of the shopping trip was a drain on my patience. I was eager for us to complete the chore and descend to the beach below for the day's sunbathing, where I would at last be able to use the telescope — oblivous to the danger of polluting the instrument with salt and sand. Time dragged. The family, regardless of my efforts to speed them up, moved slowly through a treacle crowd with leaden feet. But at last we were returning down the path toward "the front." This time, although my impatience and the slope of the hill begged me to careen down the tarmac pell-mell, I plodded carefully and slowly, lest I drop the valuable package I now clutched underneath my arm.

The sky was a deep boundless blue, and the beach would have been an oven had it not been for the brisk breeze whipping in from the sea. Small cottony clouds hurried through the air, occasionally winking the Sun out as they passed overhead. Whilst the rest of the family busied themselves with depositing their clothes in untidy heaps on the sand, I joined the telescope to its elbow tripod and set it down. I lay flat on my stomach, the hot sand stinging my skin, and with my heart in my mouth began scanning the smooth distant horizon for unseen ships. One or two swung in and out of view. I had yet to master magnified motion. Through the shimmering heat I watched, fascinated, the top part of a ship progress from left to right along the wire-taut line of the horizon. Dad was soon down on his stomach beside me, squinting down the tube at distant cliffs and bodies bobbing in the water. But the sightseeing was short-lived. Gusts of wind were managing to launch sand grains into the air; we could hear them tapping on the enamel tube of the scope like a distant machine gun. I was sensible enough to return the telescope to its cocoon of packing. It was not to emerge again until evening.

By the time dinner was finished, the cool balmy evening had replaced the hot hectic hours of the day. I left the clatter of the dining room, having wolfed down my food and finished well before anyone else, and walked out onto the large open patio that adjoined it. The Sun had already set in the west, and the last purpled remnants of a crimson dusk were turning indigo. Above my head, stars that were yet to become familiar to me twinkled in the humid air, and a pale gibbous Moon hung serene and demure in the south, speckling the Atlantic with ivory glitter. I ran upstairs to my room for the telescope, returning moments later to proudly assemble my new possession on an iron coffee table. I aimed south and looked upon the telescopic Moon for the very first time.

I do not remember quite what I expected, but I was totally unprepared for the view that focused before my eye. There were mountains on the Moon, vast curved ranges of them. What had appeared featureless seas to the naked eye were now pockmarked dusky expanses strewn with pits and boulders. There were sinister cracks and bright lines radiating from obscure

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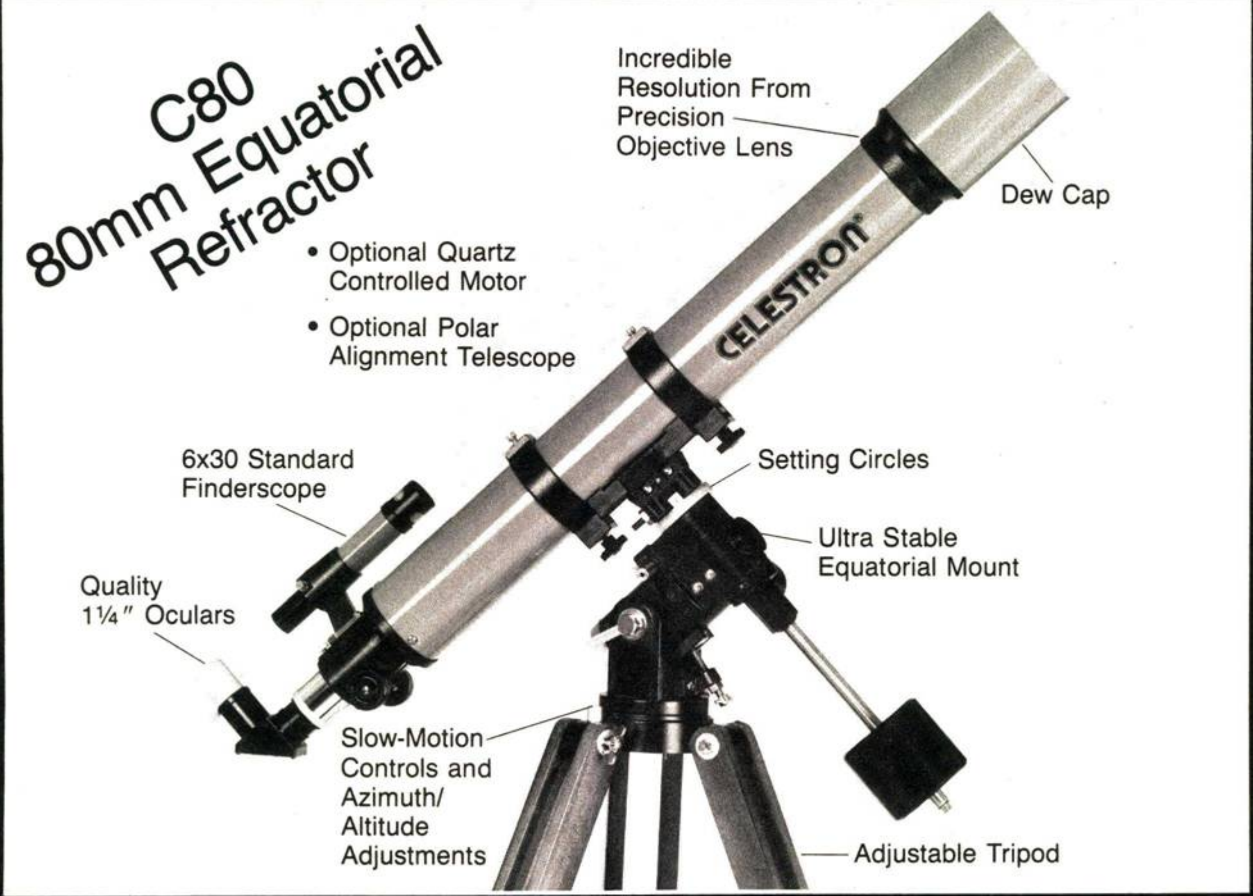
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sources, and smudges were painted randomly across the mare. I was alone. Speechless. Had company been with me I could still have said nothing, so engrossed was I in the first shaky low-power vista of the lunar surface. There were no tremulous earthquakes, no fiery bolts of lightning — but from that moment, with the catalyst of that first selenic gaze, the crystal of astronomy began to grow within me.

Totally preoccupied, I had not noticed the gaggle of curious French waiters who had gathered around me. My trance was shattered by the nearest one when he suddenly asked, three inches from my ear in broken English, what I was doing. As soon as I told, he begged me for a look at the Moon, whereupon his request was echoed by a chorus from the others behind him. One by one, they sat awkwardly in the chair and blinked at their first look at the Moon through a telescope. I refrained from telling them it was the same for me, as I found it pleasurable to have become — in their eyes — an instant authority on the subject. My rather shaky knowledge of the Moon at that time was stretched to its limits as I tried to answer their rapid questioning. I believe I satisfied them, but probably only because their grasp of astronomy was even less than mine.

People began to drift onto the patio in twos and threes as dessert and coffees were finally consumed. I noticed a few quizzical glances out of the corner of my eye, but except for one young couple, no one else disturbed me. The waiters had disappeared like a cloud of busy flies upon discovery by the head waiter, who had come looking for his missing manpower. The rest of the family joined me briefly, and each took a turn at the eyepiece. But they soon wandered off for the customary evening walk, leaving the telescope and me to scan the heavens. Stars were a grave disappointment. I had not realized that magnified points of light are still points of light, though brighter. But I was entranced, and by the time they returned, the family found me in more or less the same position.

I spent a long time on that first evening gazing at the variety and immensity of the universe from my humble coffee table. Eventually, Earth's rotation claimed the Moon as it followed the Sun into the western horizon. It was dark and still when I at last returned the telescope to its box, ready for another day. It served me well for many years to come. When I bought my 3½-inch reflector, I gave it away to a younger enthusiast, an action I now regret. I like to think it is still in use, somewhere, leading an embryo astronomer on the first hesitant steps into space.

Stephen D. Ringwood
Essex, U.K.

In Praise of the 6-inch f/8

The last few years have been good ones for reading about telescopes in ASTRONOMY. We've learned about the Yerkes and Hale telescopes, and numerous articles have appeared about binoculars, solid mounts, and resurrecting the 2.4-inch refractor. We've read about, and perhaps even participated in, the revolution in telescopes — the Dobsonians, the Poncet mounts, and mass-produced Cassegrains. I love reading about telescopes almost as much as I love looking through them. With all the telescopes to choose from, I wish I had one of each. But between the portability of the commercial Cassegrains and the large aperture of the Dobsonians, I hear said that the 6-inch f/8 Newtonian — long the standard beginner's telescope — has taken a back seat.

What? The trusty old 6-inch f/8 relegated to the back seat? This just can't be! I'm not taking a back seat to anyone!

Hold on, calm down. What's popular is popular. But I can't resist defending the 6-inch f/8 Newtonian. You see, I'm a relative newcomer to astronomy. I suppose I had always been a latent astronomer, but the seed sprouted four or five years ago. On a whim I ordered a $20 telescope from Sears. I knew I wouldn't get the best for that kind of money, but the ad said "200x" and I knew that was powerful. When it came I looked at the Moon, and within half an hour (when the telescope stopped shaking), I was hooked.

The next day I dashed from the library to the planetarium to find all I could read about telescopes, how they work, and what you can see with them. One thing led to another; I caught telescope fever and ended up with a (you guessed it) 6-inch f/8 Newtonian. It was one of several on the market, with clock drive, equatorial mount, setting circles, finderscope, two eyepieces, and best of all, a full "one-year-satisfaction" guarantee. The first year I was very critical — just looking for a reason to return it. I bought two accessories right away, a 40mm wide-angle eyepiece for low power and a 2x to 3x Barlow for the high powers.

But my telescope fever didn't end with the purchase of this telescope. I sent away for brochures from every major telescope manufacturer. I considered buying mirrors and making my own for less. Whenever I was done figuring all the relationships between focal length, aperture, magnification, and exit pupil, I kept coming back to the 6-inch f/8. I never did return that telescope.

I'm a typical tourist of the universe. I don't specialize. When I'm looking for deep-sky objects I think it would be great to have that 29-inch Dobsonian. Then I think what a waste that would be living so close to the city lights; I'd have to take it out to the country. But it's too big to be portable, so an 8-inch Cassegrain would really be nice because that's very portable. But with that long focal length I'd never get that 5mm exit pupil. Maybe a 10-inch f/4.5. Great. But then with that short focal length, how would I ever get high magnification views of the planets?

When I go backpacking or fly home to New Hampshire, I'd surely appreciate a super-portable telescope to take advantage of those nice clear skies. I can't even begin to think about taking my telescope on the plane. One of those little 3-inch Maksutovs with all those features would be just the number. The only problem is that it would cost three times what I paid for my 6-inch and still have only half the aperture. My 6-inch f/8 is portable enough to put in the back of my compact car and leave room for the wife, kid, and belongings for a weekend trip — even if I can't take it on a plane with me.

I've built up the accessories to help me with my different observations. I have a good set of eyepieces, color filters for planetary viewing, nebular filter, solar filter, and right ascension and declination slow motion controls. I made a 12-volt powered drive corrector for photography and viewing away from home. I've logged almost all of the Messier objects, cleanly split double stars down to one arc-second, and followed the phases of Mercury, Venus, and the Moon. I've seen surface features on Mars, Jupiter, and Saturn, and watched both sunspots and comets come and go.

I realize that mine is not the ideal telescope for either deep-sky viewing or planetary viewing, nor the utmost in portability. That's true. It's really not perfect for any one thing. But that's the whole point I'm trying to make: It's perfect for *everything*. I can't think of another telescope that has a better combination of versatility and portability. As I said before, I'd like to own one of each type of telescope, but until I do I'll stick with my 6-inch f/8 Newtonian. I may be riding in the back seat, but then again, back seats have more room.

— *James J. Saraceno*
Glendale, MO

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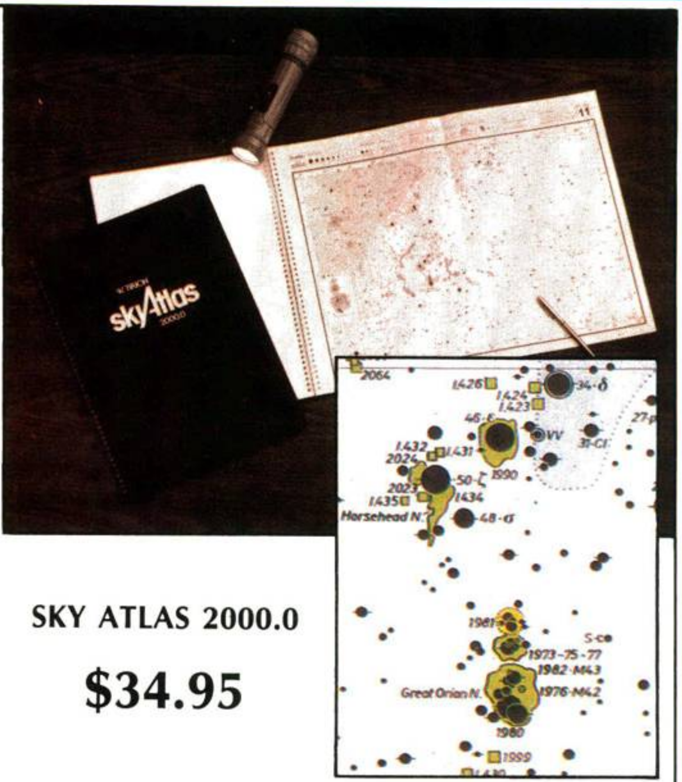

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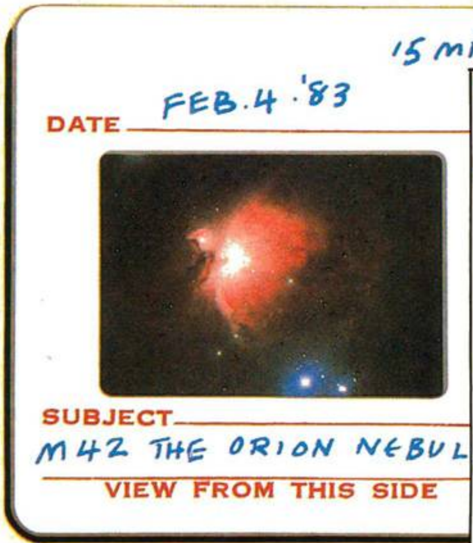

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The Tragedy of the Space Program

Sir / Don Lago's eloquent essay on "The Tragedy of the American Space Program" (November 1983) is outstanding in its description of the intellectual aspects of the problem, but his conclusion leaves us with a rather pessimistic vision. Halfway through a year-long research project on the pro-space movement, I would argue that the future may be brighter than Lago implies.

Opinion surveys show that public support for the space program has been rising since 1975, while negative opinion has declined significantly. The Congressional Space Caucus, formed in 1981, now includes 162 professional politicians who have declared themselves interested in space.

Since the mid-1970s, pro-space groups have proliferated remarkably, reflecting more than anything else the greatly increased involvement of young people. Though most of those groups are small and lack influence, at least four have more than 5,000 members. (The Planetary Society is the largest, at about 150,000.)

Some of the pro-space people are becoming increasingly sophisticated in working the Washington system, while others are demonstrating entrepreneurial talent. With intelligent leadership, this growing constituency for space could be turned into more of a political force than it is today.

Michael A.G. Michaud
Bethesda, MD

Daedalus Doings

Sir / Concerning Paul Patton's article on the Daedalus project (October 1983): I'm a bit curious why the Barnard's Star system was chosen. It is an M5-type dwarf with an "ecosphere" — a zone of Earth-like habitability — that is very small compared to the Sun's. The triple star system of Alpha Centauri is closer (4.3 light-years) and sports more variety in its ecospheres. Another possibility is Lalande 21185 (8.2 l.y.) or Epsilon Eridani (11 l.y.). (Epsilon Eridani is a K2-type star, roughly similar to the Sun.) Other candidates are 61 Cygni (11 l.y.), Epsilon Indi (11.2 l.y.), and Tau Ceti (11.8 l.y.).

My point is that Daedalus is an exciting idea and ought to be sent to a destination substantially more interesting than Barnard's Star — even if the trip is only on paper. If the search for life is a major objective of the probe, there are much better targets than Barnard's Star.

John H. Hanson
Westerly, RI

Mr. Hanson / Barnard's Star was chosen because at the time the study was begun, it was the best candidate astronomers had for another solar system. But as you note, a choice made today would probably be somewhat different. In any case, the actual destination for Daedalus is relatively unimportant since a look at any other star system from close up would be a gigantic advance on what we know.

Sir / Why couldn't you simply turn the Daedalus probe around and slow it down with the fusion engines? This seems to make the mission more propitious and the data collection much easier and less haphazard.

Todd Kvamme
Saratoga, CA

Mr. Kvamme / In theory that is exactly what you'd do — provided you had enough fuel. The problem is that from an engineering standpoint, carrying fuel for braking the ship's speed at the destination is difficult and wasteful. Remember, the fuel used to slow the ship is just so much dead weight to be accelerated to 12% light-speed when you leave the Sol system. Apart from its own mass, the extra fuel also calls for a larger structure to contain it, which in turn calls for more fuel, and so on. This problem isn't insolvable — just extremely expensive. Instead, the designers wisely chose a plan that focused on the minimum mission; this way, Daedalus (or its descendant) has a much better chance of flying.

The Project Daedalus report is still available from the British Interplanetary Society, 27/29 South Lambeth Rd., London SW8 1SZ, England. Write to them for details regarding price.

Matching Eyepieces

Sir / Some time back, I read an article that explained the longest practical focal length to consider when purchasing an eyepiece. The idea was that beyond a certain focal length, the eyepiece was limited by the observer's eye. There were formulas — and as it turned out, a 28mm was just right for my 10-inch f/5.6 Dobsonian.

This subject has now come up in our club with some of the newer members. Can you supply the formulas for us to use?

Wally Pursell
Baton Rouge, LA

— The formula is simple: Multiply the telescope's focal ratio by the diameter of the desired exit pupil to obtain the eyepiece focal length. When the exit pupil is smaller than 7 millimeters, all the light exiting the telescope should be able to enter the pupil of the observer's eye — so 7 millimeters is the maximum desirable exit pupil. For in-city viewing, where the pupil never fully expands due to stray light, or for older observers whose pupils can no longer expand to 7 millimeters, use 5 millimeters instead.

Your f/5.6 telescope will give a 7 millimeter exit pupil with a 39mm eyepiece, and a 5 millimeter exit pupil with a 28mm eyepiece.

Making Do

Sir / Since about age 15, I have been hooked on astronomy. I've been outdoors almost every clear night to look at the stars. I have viewed three lunar eclipses, many of the major meteor showers, and several planets and conjunctions. Just this summer I saw one of the most beautiful auroras in my life. I currently have a small, very wobbly telescope, but make do the best I can. Due to my financial situation, I can't afford a high quality telescope.

As I see it, astronomy is a very important part of my life. It is a learning experience, and also an interesting and relaxing hobby. I'm glad I got hooked because I would have really missed out on something if I hadn't. The bug is in me and I'm sure it will never leave. I am looking forward to May's solar eclipse and Halley's comet. At 16 I've got a lot of adventures ahead. Thank you for your great magazine.

Johnnie Andrews
Central Square, NY

Starlight Scopes

Sir / While serving in Europe with the Canadian Forces, I had an opportunity to use a Starlight scope — a portable light-intensification device that runs on a penlight battery. Superficially, it resembles an ordinary spotting scope. Unfortunately, I was unable to get technical specs on it, but it has approximately 4x. When I turned it on Orion, I could make out the nebula (M-42) in crystal-clear detail.

The only drawback (other than that the thing is available only to the military) is that the image is green. The sharpness of the image was very impressive!

R.D. Newman
Toronto, Ontario

Asleep While He Observes

Sir / As you pointed out in "A Symposium on Telescope Control with Micros" (December 1983), there is a subtle but important distinction between micro control systems that are an aid in pointing a general-purpose telescope, and data-gathering systems where the telescope simply acts as a light-gathering subsystem. In this latter case, the micro provides increased efficiency and operates the system while the astronomer sleeps. I thought you and your readers might be interested in hearing just how efficient this type of system can be.

At Fairborn Observatory West in Phoenix, Arizona, Louis Boyd has designed and built a fully automatic photoelectric telescope. It features a 10-inch Newtonian on a specially designed mount controlled by a single stepper motor in each axis. Each clear evening, as soon as the sky gets dark, the telescope automatically slews to the first star and executes a "hunt and lock" routine that finds and centers the star in a small diaphragm.

The computer then commands the photometer to take three 10-second integrations in the U, B, and V color bands (with another stepper changing the filter positions), and slews the telescope on to the next star.

Stars are observed in groups that contain measurements of the variable star of interest, plus comparison and check star, and readings of the sky background light. Some 33 measurements of 10 seconds each comprise a group, and about 75 groups are observed each night. The system totals about 2,475 measurements on a typical night.

Roughly two-thirds of the telescope's time is spent in making the actual observations, while the other third is spent in moving between stars, finding and centering stars, changing filters, or waiting while the computer reduces data or decides what to do next. There is no eyepiece on the telescope, and Boyd sleeps while his computer collects data on spotted RS CVn stars.

Russell Genet
Fairborn Observatory
Fairborn, OH

— Boyd's telescope and other highly automated systems are described in a new book, Advances in Photoelectric Photometry, Vol. 1 *(Wolpert and Genet, 237 pages), available directly from Fairborn Observatory or from AstroMedia for $23.95.*

behind the scenes

Amateur Science

Astronomy is science. In the modern world, some people are paid to "do science." Doing astronomy as science usually consists of teaching courses at a university, applying for research grant money, and conducting a research program pretty much of your own choosing with that grant money — either with or without assistants. Before this century, professional astronomers didn't exist: you either had enough money of your own to support your own research interests and did astronomy, or you didn't and you didn't.

But there have always been some people in the middle, people who followed a full-time job or profession by day, and a part-time pursuit of astronomy by night. The work was and is, quite literally, a labor of love. That's what "amateur" means — remember that venerable first-year Latin conjungation from "amare," to love. Amateurs are not unique to astronomy: there are amateurs in theater, baseball, and archaeology, to name just a few.

In this century, and especially since World War II, the gap between amateur and professional astronomers has grown steadily. Amateurs had only time, but the professionals had equipment, money, and mathematics. Professional astronomers, in some cases, set themselves apart from the amateurs, or lost themselves in their love for their work.

But the 80s and the coming 90s are different. Astronomy has grown too big for professional astronomers. An X-ray astronomer may very well be ignorant of planetary astronomy, and a theoretician who studies the intricacies of supernova explosions using complex hydrodynamics codes on fast computers may be unable to name a single star in the night sky. Amateur astronomers may well exceed professionals in hardware and computing expertise. Clearly the time for increased cooperation has come.

Paul Maley's article, "Measuring the Shape of an Asteroid," on page 51 of this issue, describes an outstanding example of the new links being forged between amateurs and professionals. All of you who participated in this experiment — as amateurs, hobbyists, or dabblers in astronomy — made a useful contribution to human knowledge. Whether you drove miles and miles under cloudy skies looking for the clear spot that never appeared, or watched for an occultation that you knew probably wouldn't occur where you were, or actually *saw* 1 Vulpeculae blink off and on again, we at ASTRONOMY salute you.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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A Lunar Sampler

Gazer's Gazette

by
Don Spain

Remember your first telescope? No matter what size it was — a 40mm spotting scope, a 60mm department-store refractor, a commercial or homebuilt 6-inch reflector — one of the first, if not *the* first, celestial object you observed was the Moon. Remember the excitement of following the terminator night after night as the Moon grew from a thin crescent to Full?

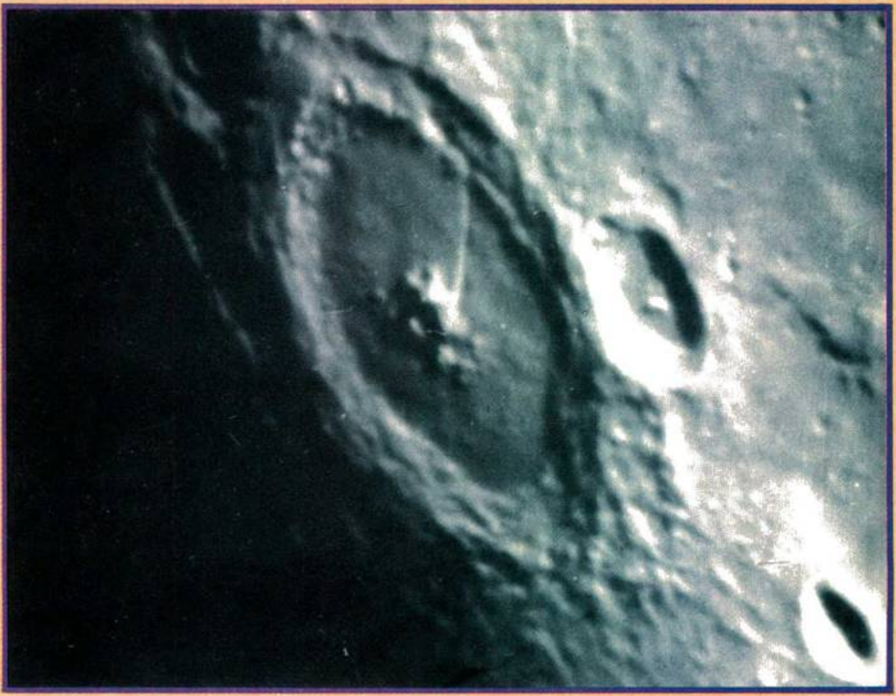
You quickly learned the location and names of the more prominent craters, mountain ranges, valleys, and maria. With more experience you found many of the more obscure features: narrow ridges, deep crevices, peculiar craters, isolated peaks, domes, and faults. After six months of intensive lunar study you were probably more familiar with the general geography and geology of the near side of the Moon than with that of the Earth. And probably, too, with this knowledge your interest in our nearest neighbor began to wane.

Other types of observing started to compete with the Moon for your viewing time. The planets, double and variable stars, and deep-sky objects soon reduced the Moon to a secondary observing target. As your telescopes became larger and faster, you may even have begun to curse it. When the light from the waxing Moon blotted out those low-contrast galaxies and nebulae, you put your scope away for 8 to 12 nights a month.

Well, while you have forsaken the Moon, she has not forgotten you. Her craters, mountains, and maria still appear out of the frigid lunar night, warming quickly under the intense heat of the Sun and slipping back again into the chilly dark 14 days later.

As the terminator rolls westward across the face of the Moon, many features that you never observed are beckoning you — and the old friends you knew so well are waiting to welcome you back. What follows is a lunar sampler: descriptions of five of the largest formations, all easily visible in small instruments. Some you may remember well, others were just acquaintances, and some you may never have met.

It's a sneaky thing to do, trying to reconcile you with your first love — and a little risky, too. But it's worth the attempt; besides getting full use out of your optics, observing a delicate cleft or a tiny craterlet at the limit of your objective's resolution can be just as rewarding, or as frustrating, as trying to spot a faint extended galaxy or splitting a tight double star. So don't throw those "white nights" away — instead, turn your scope back on the Moon!



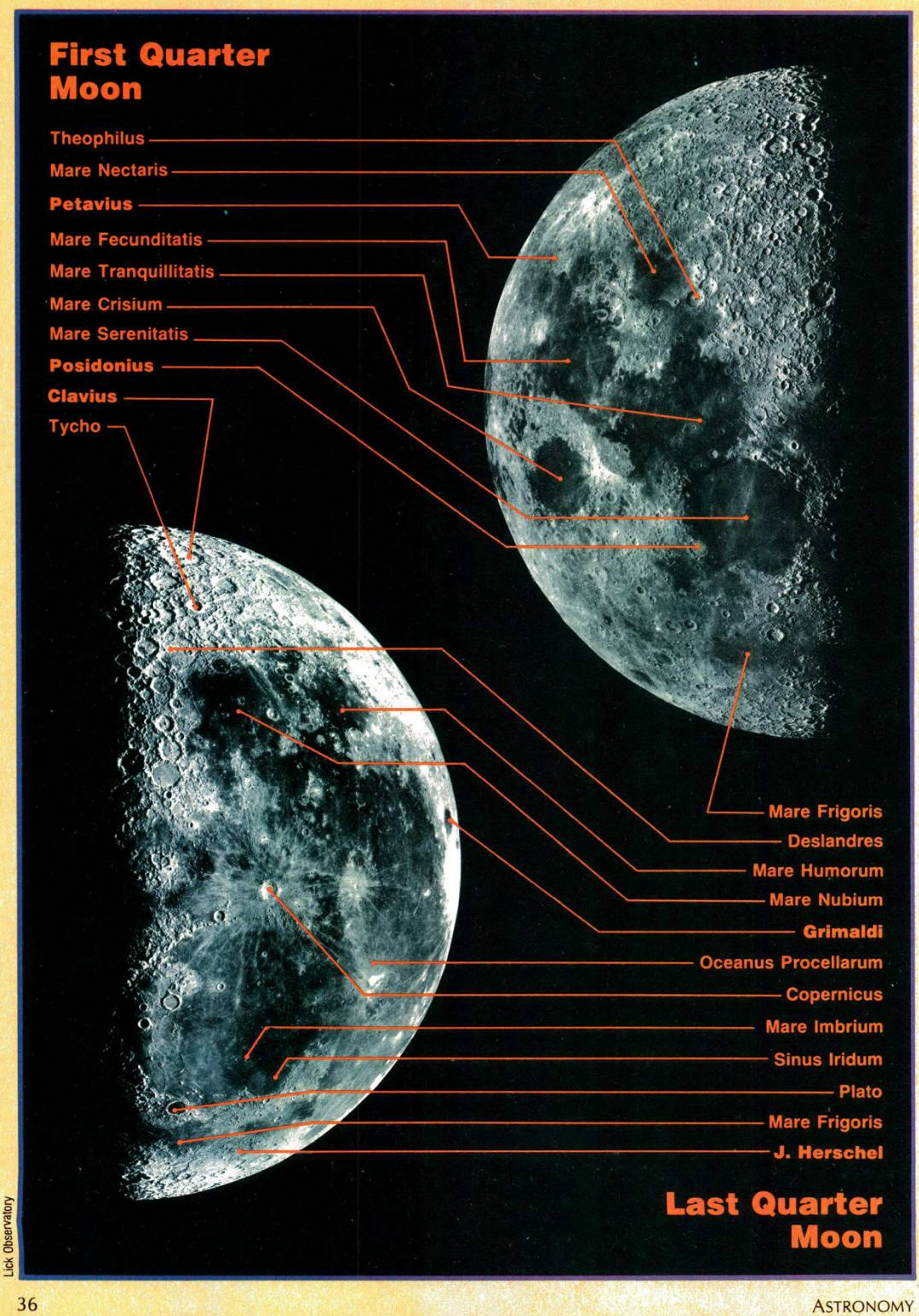
The low walls, central peak massif, and slightly arched floor of Petavius show clearly in this photo taken by Jean Dragesco under evening illumination a few days after Full Moon.

Petavius

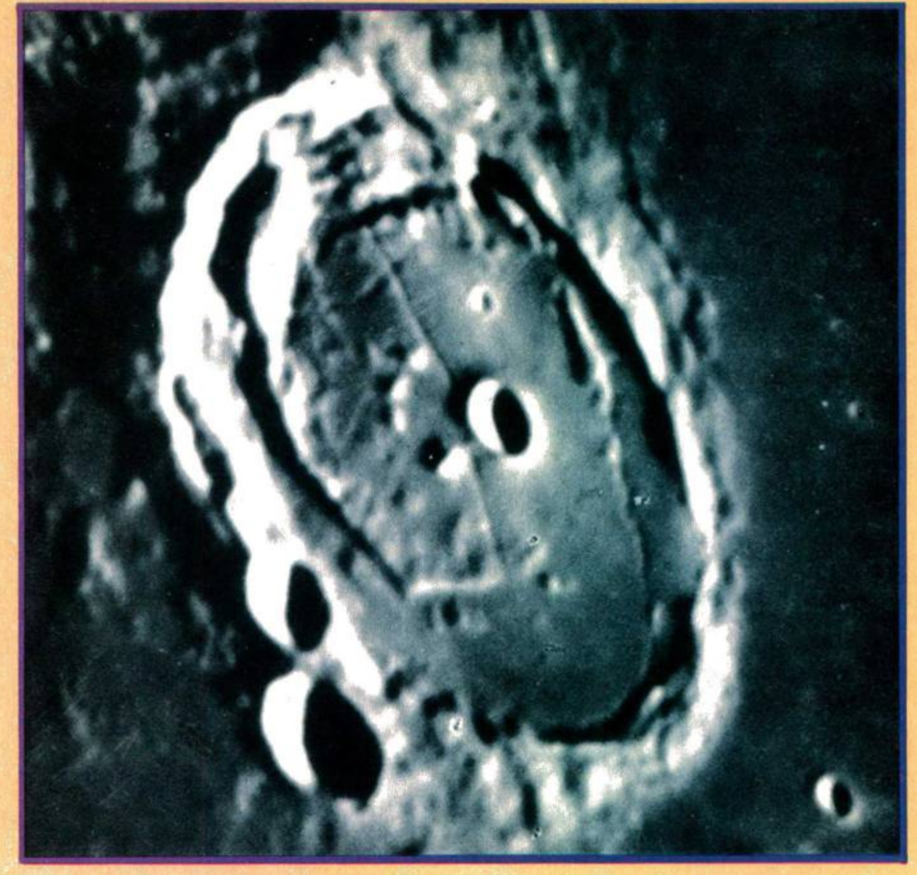
This huge formation, located near the southeastern limb at 25° south latitude and 60° east longitude, becomes visible under a rising Sun about three days after New Moon. It is also well placed for observation under a setting Sun one or two days after Full Moon. Under grazing illumination, Petavius dominates its area.

About 110 miles in diameter and with outer ramparts 11,000 feet high, this is truly one of the most magnificent craters on the Moon. If it were closer to the center of the near side, it would give the better-known craters like Tycho, Plato, Clavius, and even Copernicus a real run for viewing time.

Petavius' surrounding walls are very complex — terraced and doubled in many places. These mountains enclose a slightly convex floor. Only one small crater on the floor is visible in small telescopes. This is 3-mile-wide Petavius A, located just south of the central mountain group. Even large backyard telescopes will not reveal other craters on the floor. A small crater, C, on the southern ramparts is easily visible in


First Quarter Moon
Theophilus
Mare Nectaris
Petavius
Mare Fecunditatis
Mare Tranquillitatis
Mare Crisium
Mare Serenitatis
Posidonius
Clavius
Tycho
Mare Frigoris
Deslandres
Mare Humorum
Mare Nubium
Grimaldi
Oceanus Procellarum
Copernicus
Mare Imbrium
Sinus Iridum
Plato
Mare Frigoris
J. Herschel
Last Quarter Moon

Lick Observatory



The floor of Posidonius — largely flooded by mare material — displays a few craterlets, some remnants of peaks, a hint of an inner ring of mountains, and several rilles. Lick Observatory photo.

small instruments.

The central mountain group forms a complicated system with many detached peaks. The major peak reaches 5,500 feet above the floor. Three rille systems radiate from these mountains. The major rille, Rima Petavius I, runs to the southwest and shows up in quite small telescopes. Rima II is much more delicate and extends almost due north from the mountains. Rima III is very faint and terminates at Petavius A. You'll find you need medium to large apertures to spot Rima III.

Posidonius

Located on the northeast shore of Mare Serenitatis, at 32° north latitude and 30° east longitude, is the grand walled plain of Posidonius. It lies on the terminator five or six days after New and again some six days after Full. Probably the main reason that Posidonius is not observed more often is that the great crater Theophilus is on the southern part of the terminator at the same time. Pull your attention back north to Posidonius and you will not be disappointed.

With a diameter of 62 miles, this plain is visible in any scope, although its enclosing walls are not particularly high — perhaps 7,000 feet on the eastern rim and much lower in the west. In fact, at one place the western wall appears completely open to Mare Serenitatis.

Much detail crowds the interior floor. Among at least four rille systems, the easiest to spot is Rima Posidonius II. It lies near the western walls, runs almost north-south, and can be picked out with a 3-inch scope. The other rilles all lie to the north and east of Posidonius A. An easy object, Posidonius A is about 7 miles across and is the only crater of any size on the floor. Posidonius C, to the southeast of A, appears tiny — it's only 2 miles across. Also rather shallow, you'll find it difficult to see except under grazing sunlight. The last crater of note is Posidonius B — look for it on the northern wall. It is a little larger than A.

A distinctive feature of Posidonius is the half-circle of hills that lies inside and parallels the north, east, and south rim. Much higher in the east and disappearing at the northern and southern ends, these hills suggest an ancient, almost totally demolished inner ring. Also note the several isolated hills near the very center of the floor.

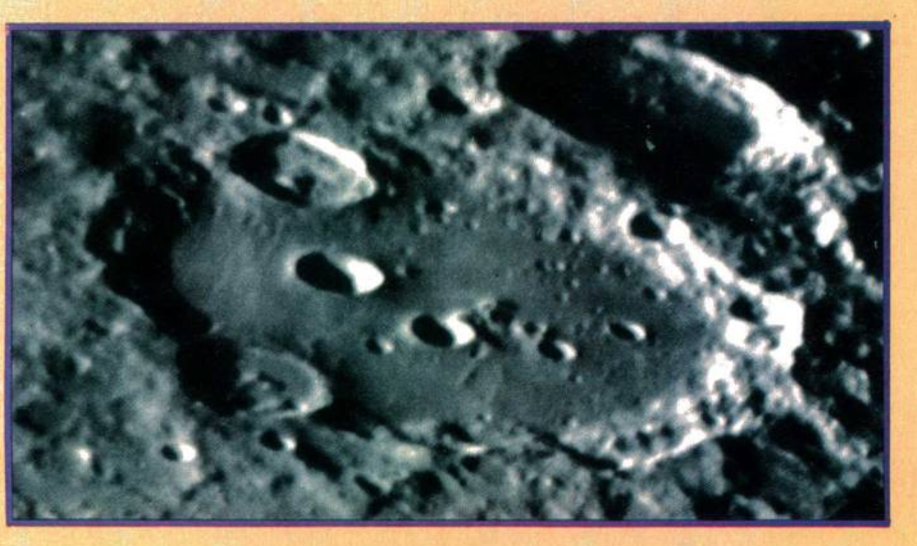
Clavius

In the southern highlands, at 58° south latitude and 15° west longitude, you will find the gigantic mountain-walled plain of Clavius. When observed around two days after First Quarter, it overshadows everything else on the southern part of the Moon.

Boasting a diameter of 140 miles, Clavius can lay claim to being the second-largest structure on the near side of the Moon, excluding the maria. (The inconspicuous, ruined crater Deslandres is slightly larger.) The circular mountain range that forms Clavius' walls rises at least 12,000 feet above the plain, with some individual peaks much higher. The crater Porter (32 miles across) breaks the mountains on the northeast wall while Rutherford, at the same size, intrudes somewhat into the southeast wall.

Despite their respectable diameters, these two craters seem to pale to insignificance when compared with Clavius. But each has considerable detail on its floor and both have central peaks. Porter has a nice craterlet on its northwestern wall.

Located midway between the two is Clavius D, about 18 miles across. It is the largest of four craters arranged in a semicircle whose neat pattern has led some observers to postulate a volcanic origin for them. All are easily visible in a 2-inch refractor. With a good 8-inch scope and good seeing you should be able to resolve nearly a hundred craters and craterlets on the floor and walls. Almost



Though it lies amidst very tangled terrain, Clavius is still quite distinctive. Its shallow appearance is deceptive, since its walls rise two miles above the crater floor. Photo by Jean Dragesco.

all of the floor craters lie on the western two-thirds of the plain; the area that spreads east of D lacks all sizable craters.

Craters apart, the floor of Clavius is remarkably smooth. With the exception of a few small hills near the center, Clavius has no peaks on its interior — and apparently no rilles or clefts, either.

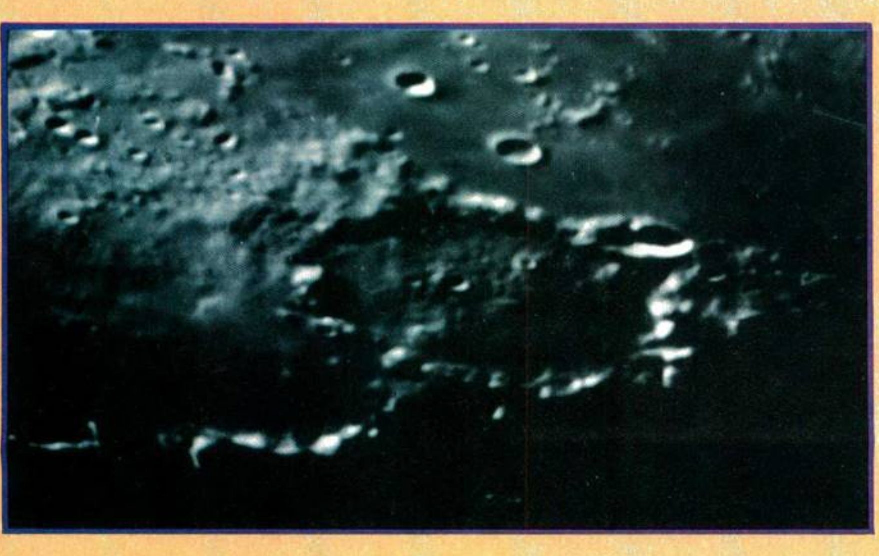
Clavius makes a superb target at any lunar phase: when near the terminator, its relief stands out boldly. And as the Sun climbs in altitude toward Full, see if you can distinguish the different shades of grey on its floor.

J. Herschel

About three days before Full Moon is the best time to look for the old walled plain, J. Herschel. Located near the northwest shore of Mare Frigoris, at north latitude 62° and west longitude 40°, J. Herschel eludes most observers' scrutiny. Besides its extreme northern location, it is also difficult to discern due to its very subdued relief.

Yet this crater is another of the behemoths, stretching 97 miles across the surface of our sister world. Its low walls attain a height of only a few thousand feet and in several areas are almost nonexistent. Because the shadows cast by these low hills rapidly disappear as the Sun rises, you must catch this formation while it lies close to the terminator. J. Herschel becomes difficult to recognize a day after local sunrise and is next to impossible two days after that.

If you're using an objective 3 inches or less in aperture, the interior appears empty at first glance. But with careful study during moments of good seeing, you should be able to spot at least four small craters dotting the floor. The largest, J. Herschel A, sits on the southern wall. Fifteen-mile diameter Horrebow in turn intrudes into J. Herschel A. An 8-inch scope will show an additional dozen or so craterlets but no central peaks or rilles. Under grazing light at sunrise, the floor reveals a rough and wrinkled appearance, especially in its western part.

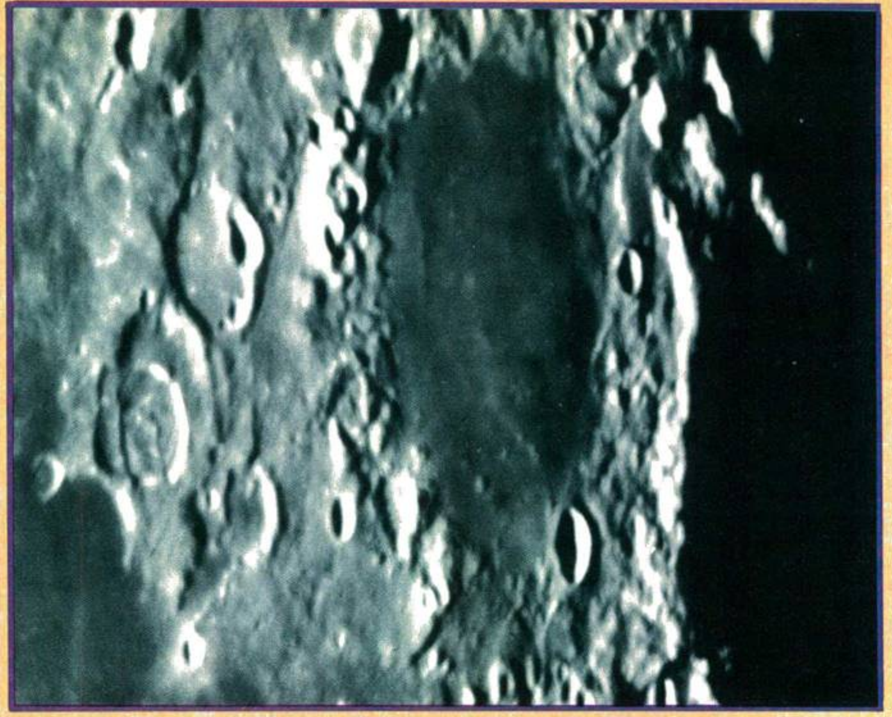


Much altered by geological events, J. Herschel shows a low, broken rim of mountains and a rough and hummocky floor. Viewing the crater under low Sun angles is a must. Photo by Jean Dragesco.

Grimaldi

The darkest area on the Moon's near side becomes visible about a day before Full. Its center is located near 5° south latitude and 68° west longitude. Sometimes classified as a walled plain, Grimaldi is really a lunar basin similar to the maria. It reminds you of a Mare Crisium in miniature.

Like most of the smaller maria, the floor of Grimaldi — almost 140 miles across — is smooth and free of hills or ridges of substantial height. This makes Grimaldi rather like J. Herschel in that you must observe it when it lies right on the terminator if you wish to see the delicate features it offers. Under low-angle lighting, you can pick out a gentle ridge that runs north-south on the southeast floor. A 3-inch scope will show a slightly roughened area on the northeast floor. The largest feature in Grimaldi is the 15-mile-wide crater Grimaldi B, located at the northwest corner of the basin. The area just south of Grimaldi B is probably the roughest of all on the floor.



Lying near the western limb, Grimaldi always appears strongly foreshortened. Its dark floor hints at probable flooding by mare basalts from Oceanus Procellarum. Lunar & Planetary Laboratory photo.

A range of low, discontinuous mountains surrounds the dark basin itself; a few of these peaks may reach 8,000 feet. Many small craters are scattered among the peaks, but few exceed 5 miles in diameter. Passes and openings in the mountains let the light from the rising Sun stream through and across parts of the dark floor while the rest remains in shadow. After the Sun has risen to light all of the floor, see if you can detect variations in darkness across the basin — the southwest area appears somewhat darker than the rest.

The Grimaldi region is one of several on the Moon that have been suspected of producing lunar transient phenomena — what appear to be brief outgassings or emissions, presumably remnants of residual volcanic activity. Although their existence is still a matter of some debate, it's always a good idea to keep at least the possibility in mind as you swing your scope once more toward our sister world — in the poet's words, that "orbed maiden with white fire laden, whom mortals call the Moon. . . ."

Don Spain lives in Kentucky and enjoys observing the Moon, planets, and deep-sky objects. He got his first telescope, a 40mm spotting scope, in 1958.

ASTRONOMY
Reviews

Composition and Origin of Cosmic Rays

Maurice M. Shapiro, ed.
414 pages, hardcover, $58.50
D. Reidel (1983)

"Although cosmic-ray phenomena have been fruitfully investigated for some seventy years," notes Shapiro, "the central enigma — the origin of these high-energy particles — remains a challenge." The fast-moving subatomic particles that make up cosmic radiation are an important element in understanding high-energy phenomena in our Galaxy. They compose about one-third of the interstellar medium's energy density. The high-energy particles that compose cosmic rays also represent the only direct and measurable sample of matter from outside the solar system. The book contains the proceedings of a NATO Advanced Studies Institute workshop on cosmic rays.

Celestron Comet Catcher

5.5", f/3.64 Schmidt-Newtonian Rich Field Telescope
Celestron International
List price: $450.00

Last spring, during the fleeting apparition of Comet IRAS-Araki-Alcock, I arranged for the loan of a prototype Comet Catcher from Celestron. I was intrigued with the Comet Catcher when I first heard about it, and was not disappointed when I used it both visually and photographically on the comet and later on other objects.

The Comet Catcher measures 19 inches in length and 6 inches in diameter, weighs 6.4 pounds, and is completely constructed of metal. A small tripod pad tapped for ¼-20 threads secures the tube to any like-threaded bolt (such as is found on a camera tripod), and the focuser — a sliding rack-and-pinion type — carries the diagonal mirror with it as it moves along the tube to focus.

I star-tested the Comet Catcher with the 18mm orthoscopic eyepiece that is supplied with it, as well as with Televue and Celestron Plossls. The images were excellent. To make the most of them, I recommend using one of the Plossl-type eyepieces, which are designed for low f/ratio telescopes. (Both Televue's and Celestron's Plossls gave good results.) The 18mm orthoscopic supplied with the telescope simply does not do justice to the image formed by the optics. My tests showed that even the Plossls had inherent residual off-axis astigmatism which was not in the primary image. Views in the Comet Catcher were nice and crisp, and the telescope is fun and easy to use for general skywatching.

I have a few criticisms of the telescope's mechanics, which I'll outline in some detail for those looking for small projects easily done in a home workshop.

The tripod pad is not at the center of gravity of the telescope when the eyepieces are used. A longer tripod pad with several ¼-20 holes in it can be made from aluminum channel and held on with large hose clamps. This will let you find a balance point no matter what eyepiece or camera rig you use.

The mis-position of the pad is minor, however, compared with the top-heavy tripod's tendency to capsize. Plan to use a heavy-duty tripod with the Comet Catcher to lower the possibility of capsizing.

There is very little distance between the end of the tube and the corrector plate. Thus there is little protection from stray fingers or dew buildup; a slide-on dew cap could easily be constructed from cardboard, plastic, or metal.

I found the telescope difficult to hold, especially when mounting it on the tripod. The tube has a slippery finish and the convex bottom at the mirror cell end allows it to stand only on the corrector-plate end — a practice definitely not to be recommended! Owners might consider adding a handle to the tube at its center of gravity for ease of mounting and carrying.

This handle will also serve another purpose — some kind of pointer, peep-sight, or finder is necessary even on a low-power, wide-angle telescope like this. Sighting along the handle will help, or perhaps you could clamp a finder onto the handle.

The focuser differs from your standard rack and pinion. Instead of moving in or out perpendicular to the side of the telescope tube, the entire eyepiece holder and diagonal move up and down *along* the axis of the telescope. Gravity thus tends to pull the eyepiece holder downhill, and the image can slowly creep out of focus. There is a tension adjustment, but holding the focus at a set point is critical and must be done carefully, over and above how you use the locking set-screw on the focuser. Moreover, both the focusing knob and single lock screw are on the same (left) side. It was hard to reach the knob and screw at the same time.

Another problem I found in sampling other Comet Catchers on display at the Riverside Telescope Makers Conference was that the lock screw shifted the focus as you tightened it — though this doesn't happen much with the scope I have. You could fix this by changing the shape of the end of the lock screw or introducing a bushing between the screw and lock surface to transfer the pressure, but not the rotation, of the lock screw to the frame.

There seems to be more hardware than necessary supporting the diagonal. If this could be cut down, the central obstruction and diagonal stem would be reduced and the diffraction pattern improved. (Celestron says they have since reworked the diagonal.) I have heard that there have been problems in maintaining collimation during shipping. Hopefully, the diagonal holder rework will solve this problem, too. I have also heard some users (like myself) rave about the good images in these telescopes, while others have found them not particularly good. Perhaps this is a result of poor collimation, which is especially critical in fast optical systems.

To use the Comet Catcher for photography, you remove the eyepiece holder and attach the camera adapter with a T-ring. This adapter has three sets of threads — one for the telescope, one for the T-ring, and one to allow the camera to be oriented as desired (a nice feature). Unfortunately, there are no projections for gripping the parts of the adapter when you mate them together and, with three sets of threads, making sure all are tight and seated deeply enough is a problem. The lack of grip points also makes unscrewing the various parts difficult.

Despite the shortcomings mentioned here, I recommend this instrument heartily. The scope is excellent and fun to use. The Comet Catcher will provide its users with many hours of pleasurable observing, and the tinkerer-types will have a few small projects to work on, if they so desire. I think of this instrument not only as a good rich-field telescope, but also as a useful "almost-Schmidt" camera.
Stephen Edberg.

Einstein's Space and Van Gogh's Sky
Lawrence LeShan and Henry Margenau
268 pages, $6.75
Collier Books (1983)

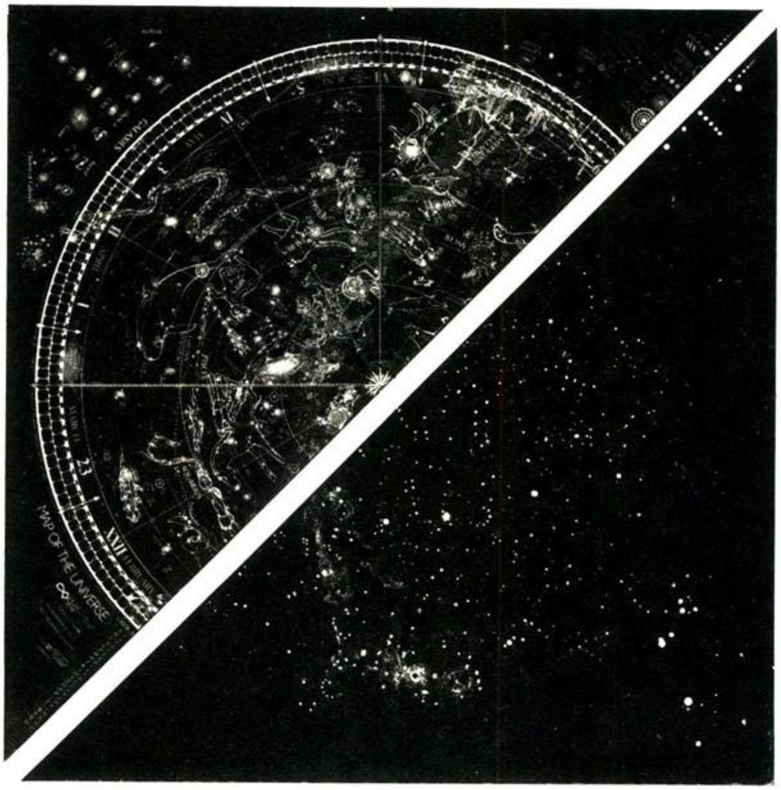
We all have been taught mathematics and science as if these disciplines articulated eternal verities graven in granite. But things are not really so simple. For example, in what sense does a geometrical idea like an isosceles triangle "exist"? And is gravity a "thing" in the real world or simply a technical term physicists use to describe one of the ways in which matter behaves?

The first of the two major parts of *Einstein's Space and Van Gogh's Sky* deals with such questions and explains the basic philosophical assumptions and mental processes that underpin the methods of the physical sciences. The authors (LeShan is a psychologist, Margenau a physicist) point out that mathematics and the physical sciences are both limited by our humanness; math says less about the structure of the universe than it says about the processes of our own minds, except in so far as our minds are themselves part of the universe. And our study of physics and chemistry begins with the senses, which are restricted by physiology. Our eyes, for example, are sensitive to only a small section of the electromagnetic spectrum.

LeShan and Margenau therefore conclude that the results of science are essentially human intellectual constructs ("The reason [the universe] is comprehensible is that we can only know it as it is construed by human beings and our own works are comprehensible to us"), and that scientific truth is "asymptotic truth" — approaching but never reaching its ideal, a complete description of reality.

The purpose of this book is, according to its preface, to find "a procedure allowing us to deal with them [the human sciences] in a systematic manner that might be said to impart to them 'reality.'" The authors believe that contemporary psychology, economics, and social science have failed, and that they have failed because researchers in those fields cling to the behaviorist approach, which maintains that human psyches and societies can be understood solely in terms of cause-effect "machine" models, despite behaviorism's repeated failures. "Each failure at prediction and control was taken as evidence that we did not yet know enough to implement a correct theory. . . .This is the definition of a pseudo-science; a nonfalsifiable field of inquiry. It is very difficult to conceive of an occurrence or an experiment that would convince a psychoanalyst, an astrologer, a Marxist, a behaviorist, or a Darwinian that the concepts of their school were invalid."

Therefore in the second major part of the book LeShan and Margenau apply *their* understanding of the scientific thinking process to the human sciences — psychology, social science, art, parapsychology, and ethical theory. In each of these domains of study they ask



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this set of basic questions: "What are the observables here? What kind of measurements can be made? What laws relating to observables can we hypothesize and test? What do the terms 'space,' and 'time,' 'state,' 'observer' mean in this domain?"

Unfortunately, whatever merit this approach may have is never realized: 100 pages is simply not enough in which to discuss *five* wildly different fields. A deeper problem is the justification for using the methods of the physical sciences on such "unscientific" areas as art and ethics; one suspects that for them a drastically different approach is necessary. *Craig Crossen.*

Evolution of the Universe
I.D. Novikov
176 pages, hardcover, $14.95
Cambridge University Press (1983)

Igor Novikov is a theoretical cosmologist at the Space Research Institute in Moscow. This book is a translation of a work that was originally published in Russian in 1979, though a few parts have been rewritten for this edition. The book provides a survey of physical cosmology, with an emphasis on the historical development of ideas since about the 1920s. Its last chapters explore the directions future research may take.

The level of presentation assumes no knowledge of math or astronomy beyond what one learns in a European high school, though this is probably somewhat more than most North Americans get in college. Since the difficulties in much of cosmology lie more in grasping the concepts than in manipulating numbers, many laypersons here may enjoy the book without plowing though the small amount of math it contains.

Telescopes, Tides, and Tactics
Stillman Drake
236 pages, hardcover, $22.50
University of Chicago Press (1983)

In presenting his ideas in print, Galileo Galilei often used a dialog: Choosing three characters — usually a scientist, a simpleton, and a commonsensical type — he wove a debate among the three that brought out the new ideas and answered the questions posed by the fool and the intelligent skeptic.

In this book, the world's leading Galileo scholar explores how one work was received — the immortal *Sidereus Nuncius* ("The Starry Messenger") of 1610, wherein Galileo presented the first discoveries made with an astronomical telescope. Drake uses the classic Galilean technique, a dialog that extends over four days. Interspersed throughout is a running translation of the whole of the *Sidereus Nuncius,* which provides focal points for the discussions.

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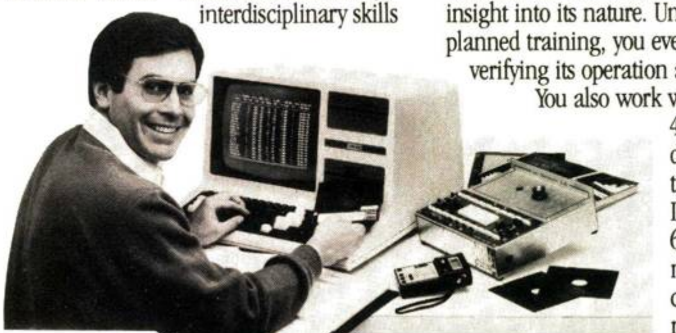

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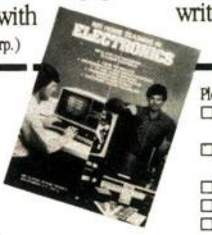

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163-024

Predawn Planet Parade

by
Fred Schaaf

Using a silvered glass globe 10″ in diameter, Douglas Brown created this all-sky photograph showing the stars of autumn. He used a 50mm f/2 lens on his camera mounted above the globe and chose Tri-X emulsion for the 5-minute exposure. At bottom left is the glow from the Moon which is about to rise.

From Monument Valley, Utah, Dewey Vanderhoff made this fine shot of Cassiopeia rising over a butte as dawn approached. For the 26-second exposure, he used a 35mm f/2.8 lens and 400 ASA film.

The Wanderers

The Moon's orbital period about Earth is roughly 29½ days, making it impossible to witness two New Moons within the month of February. This year we come as close as we can, however, since it is a leap year and the New Moon falls on February 1 in both America and Britain. Observers of the planets are fortunate that the Moon lies in the evening sky during the first week of February — this is the week when we still have a chance to observe all the planets at once in the predawn sky.

A gathering of all the planets is a rare occurrence; the most notable feature of the present one is the remarkably small angular span that contains all Earth's fellow planets in the sky. That spread increases during early February, partly because Mercury begins creeping back toward the Sun on the eastern end of the span, but mostly because the elongations of Mars and dim Pluto increase on the western end. Nevertheless, on February 10 — when Mercury might still be glimpsed 19° from the Sun — Mars is 96° from the Sun and Pluto a bit more, so that the planets remain within 90° of one another as measured along the ecliptic.

Of the naked-eye worlds, the first in this predawn parade are **Mars** and **Saturn**. On February 15, these two bodies undergo a conjunction that brings them within 48 arc-minutes of each other. At magnitude +0.5, Mars' brightness will equal Saturn's, and they both will appear about the same to your eye. But note the difference in color between Saturn's golden tint and Mars' orange glow. With a pair of binoculars you'll see the double star Alpha (α) Librae a few degrees to the southwest. A conjunction of Mars and Saturn usually occurs about two years after the previous one, but this month's is an exception — it follows a 1½-year gap. The conjunction is not as close as the one that occurred in 1978, but the only closer pairings for many decades to come will be much closer to the Sun.

On the 15th Mars and Saturn lie some 100° from the Sun — the farthest distance for a Mars-Saturn conjunction for a long time to come. Like Mars and Jupiter, Mars and Saturn undergo a conjunction near opposition only on rare occasions. Mars and Saturn almost had a conjunction near opposition in 1982, and will almost do so again this June — but their retrograde loops do not quite intersect each other at the correct angles. What is a retrograde loop? It is the path an outer planet traces on the sky for a number of weeks when Earth is overtaking it in their race around the Sun. The planet appears to slow, finally halting its normal eastward drift against the starry background. It then seems to move backward in a small loop, only to resume normal motion once again. This phenomenon is simply an effect of perspective. The closer a planet is to us, the larger its retrograde loop — but the less time it takes making the loop.

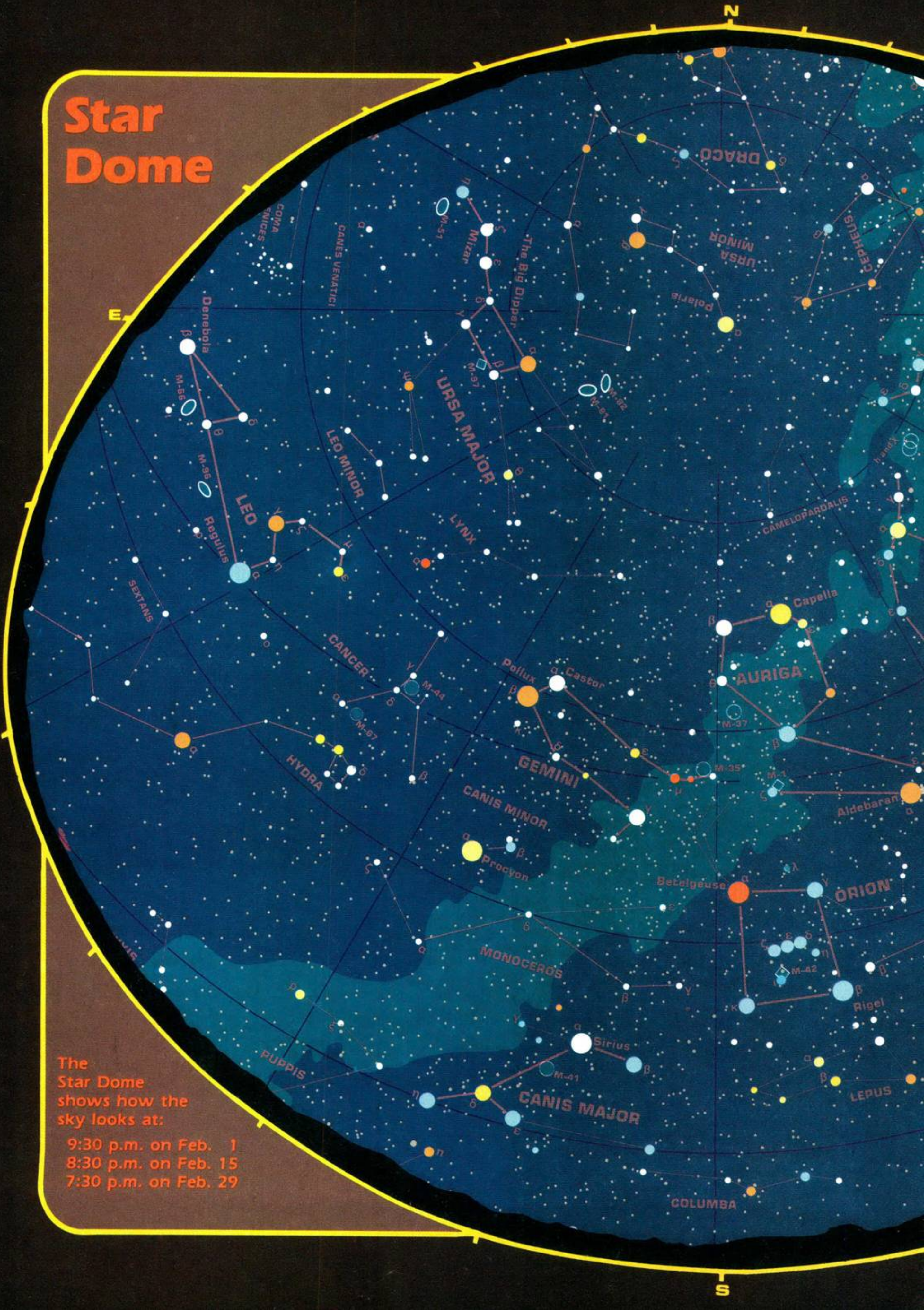
So even though Mars comes to opposition on May 11 — little more than a week after Saturn's opposition — it does not begin retrograde motion until over a month after Saturn, keeping it from catching up to Saturn again. Saturn, which presents open rings (20.9° tilt) to telescopic observers this month, begins its retrograde motion on February 25. Mars speeds across much of Libra during February, brightening impressively almost to magnitude +0.0.

Slow-moving **Uranus**, now dawdling in southern Ophiuchus about 6° from Antares, meets Mars after the latter halts to retrograde. The even fainter gas giant **Neptune** is another constellation away, in Sagittarius — where viewers with telescopes or binoculars can find it near M-20, the Trifid Nebula.

Last month, **Jupiter** and **Venus** visited Neptune and some deep-sky objects in Sagittarius, but this month they move eastward. Jupiter is much the slower of these brilliant planets — it can be found a few degrees above the top of the Teapot of Sagittarius by month's end. (Neptune and accompanying nebulae are above the end of the "spout.") Jupiter brightens somewhat to about magnitude −1.5 as it increases its elongation from the Sun.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Star Dome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HYDRA
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Castor
Capella
AURIGA
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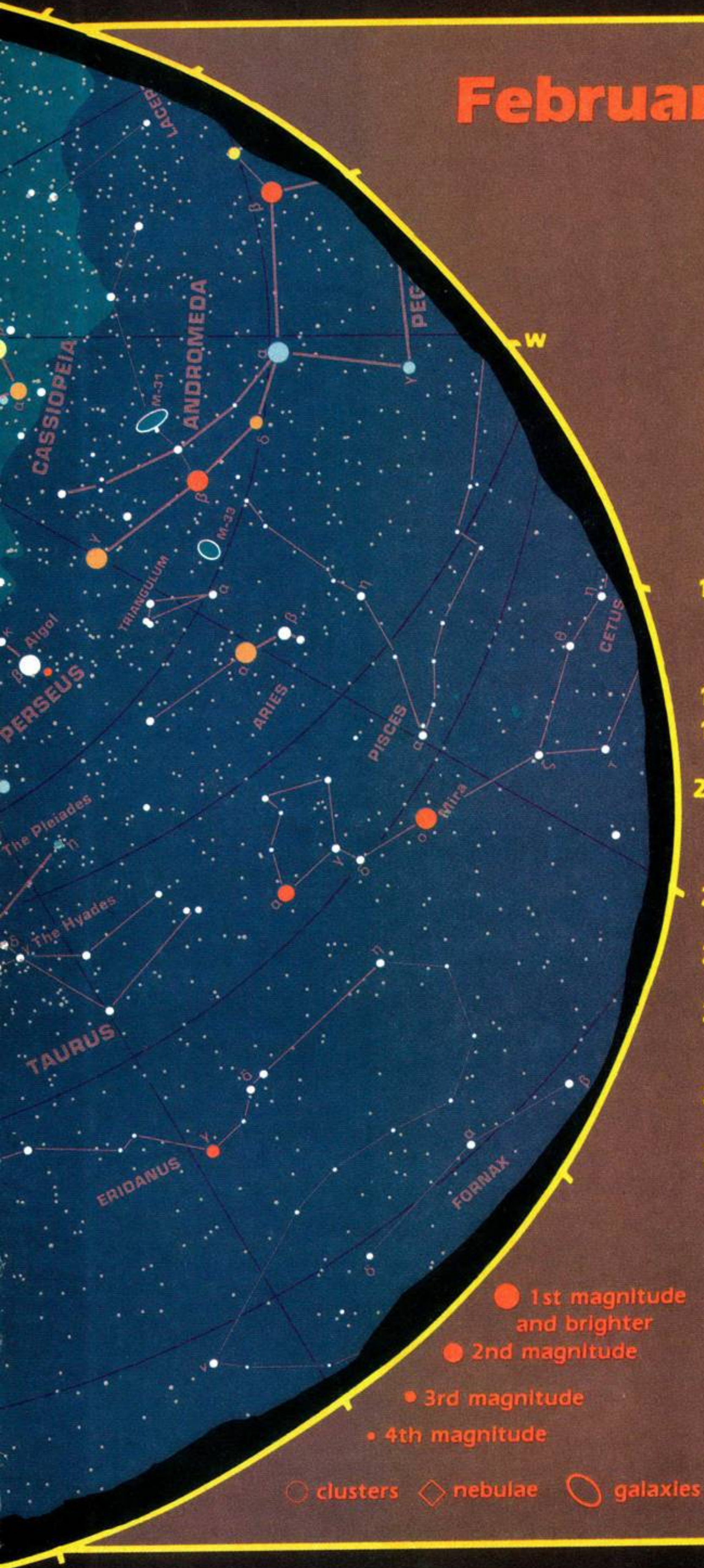
M-35
M-1
GEMINI
CANIS MINOR
Procyon
Aldebaran
Betelgeuse
ORION
M-42
Rigel
MONOCEROS
PUPPIS
Sirius
M-41
CANIS MAJOR
LEPUS
COLUMBA

The Star Dome shows how the sky looks at:

9:30 p.m. on Feb. 1
8:30 p.m. on Feb. 15
7:30 p.m. on Feb. 29


LACER
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CASSIOPEIA
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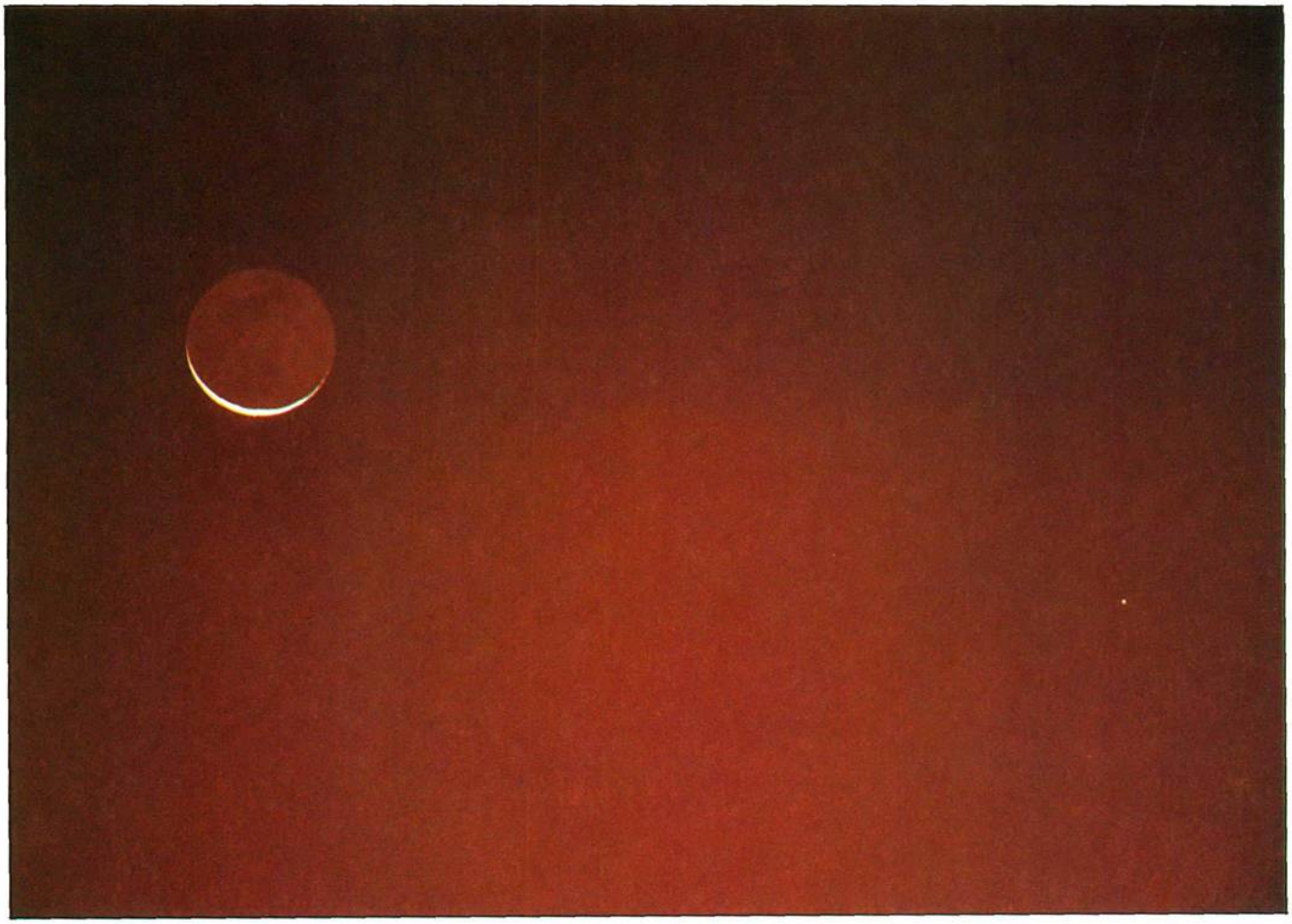
M-31
M-33
TRIANGULUM
Algol
PERSEUS
ARIES
PISCES
CETUS
Mira
The Pleiades
The Hyades
TAURUS
ERIDANUS
FORNAX
1st magnitude and brighter
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

February Sky Almanac

1st	New Moon occurs at 6:46 p.m. EST. Also, Mercury will be visible low in the southeastern sky during the hour before sunrise for the next week to 10 days.
4th	The Moon is at apogee at 4:00 a.m. EST: 252,548 miles.
6th	Asteroid Pallas is in conjunction with the Sun.
9th	First Quarter Moon happens at 11:00 p.m. EST. Also, Mercury is at aphelion.
15th	Mars will be close to Saturn in the morning sky, passing 48′ of arc south of it at 7:38 a.m. EST.
16th	Full Moon is at 7:41 p.m. EST.
17th	The Moon is at perigee at 3:58 a.m. EST: 221,650 miles.
22nd	First Saturn and then, five hours later, Mars will be overtaken by the Moon in the morning sky.
23rd	Last Quarter Moon occurs at 12:12 p.m. EST.
24th	The Moon will pass close to Uranus in the morning sky.
25th	And today it's Neptune's turn! Also, Saturn is stationary in right ascension.
26th	The Moon passes 2° south of Jupiter.
29th	Venus lies 4° north of the Moon.



On October 15, 1982, the Moon passed within 4° of the planet Mercury and the star Eta Virginis (Mercury is the brighter). Using an 8-inch f/10 SCT for guiding, Terry N. Lonner used a 400mm telephoto lens and 200 ASA emulsion. This year Mercury undergoes two close conjunctions with the Moon, on May 28 and November 24.

Venus, on the other hand, is getting slightly fainter — though it still shines at magnitude −3.4 — and closer to the Sun; its elongation decreases to 27° by Leap Day. With your unaided eye, observing on the 4th, can you see 3.9 magnitude Omicron (ο) Sagittarii just 16 arc-minutes north of Venus? Do not confuse it with the brighter Pi (π) Sagittarii or Xi (ξ) Sagittarii, which are much farther away from Venus.

Our final planet is not visible during the last week of the month, so enjoy it early. It is **Mercury**, which may be spotted with ease early in the month as the little caboose on the train of all the planets.

The Starry Sky

At mid-evening in February, **Sirius** rides at its highest point and dominates the sky, especially in a year like this one when it has no competition from planets. Everyone who looks at the night sky should pause to admire the sparkling head of Canis Major on February nights — but we should not neglect some of the winter sky's fainter attractions. This is a good month to consider where some of the splendid stars and star clusters that we admire are heading in space; compared to the duration of a February night under the stars or even a human lifetime, they seem motionless — but they are not.

Two of the fainter constellations are **Eridanus** and **Lepus**. Eridanus is the River, whose source is a fairly bright star next to Rigel, Orion's leading foot. In dark skies, follow its dim current along a vast horseshoe curve over to Cetus and back. Lepus the Hare is a more prominent constellation, yet is overlooked nearly as much as Eridanus because it is tucked neatly under the stunning form of Orion. The brightest stars in Lepus are **Arneb** (magnitude 2.6) and **Nihal** (magnitude 2.8).

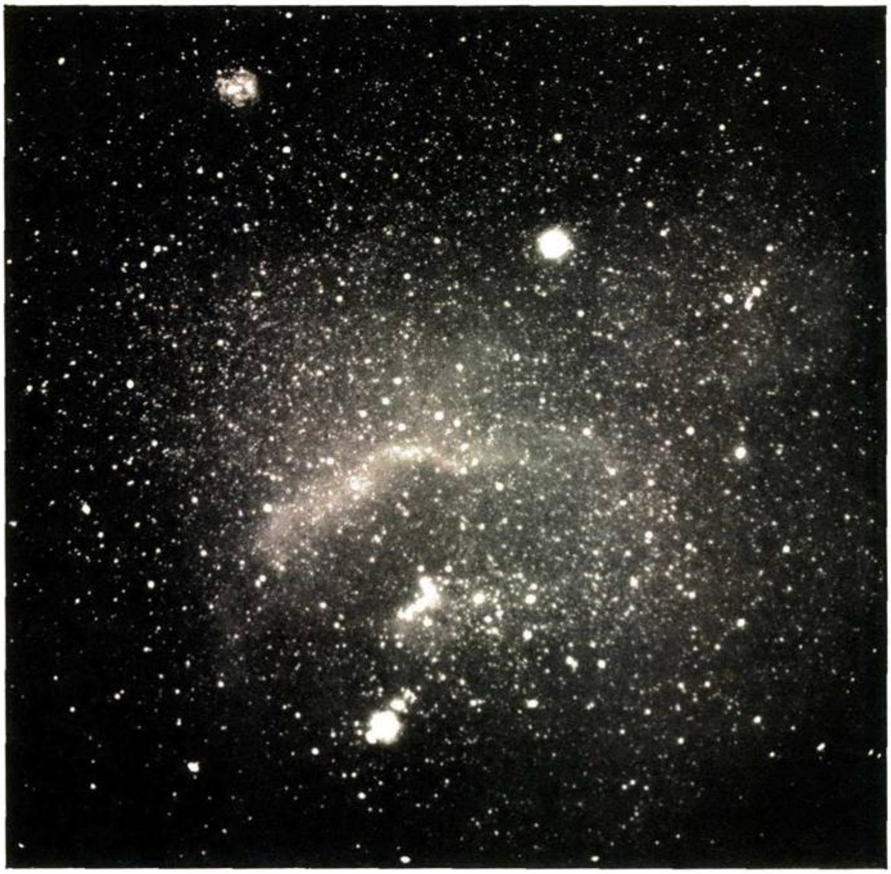
The first-magnitude stars of Taurus, Auriga, Gemini, Canis Minor, Canis Major, and Orion combine to form some giant asterisms. We'll look at some of these next month, but with Sirius at its highest elevation, we shouldn't miss at least a couple of these giant chains of stars. One asterism is called the Winter Triangle. In winter's abundance of brilliant stars, this triangle will never be as prominent as the Summer Triangle. The pattern formed by Sirius, **Procyon**, and **Betelgeuse**, however, is a nearly perfect equilateral triangle, with Procyon and Betelgeuse at about equal heights on either side of the meridian when Sirius culminates. You can see a less obvious but long-established figure by running one line from Procyon through Sirius to the star **Phaet** in the little constellation **Columba** the Dove, which lies just below Lepus, and running another line from Betelgeuse through Sirius to the second-magnitude star **Naos** in **Puppis** (the Poop of the now beached ship Argo). This gigantic pattern with Sirius at its center is called the "Egyptian X."

Both Puppis and Columba are quite southerly and therefore inconspicuous constellations for most readers, but they are worth finding. Naos is a 2.3 magnitude star but its southerly declination of −40° makes it rather unimpressive. Readers who live south of 30° north latitude can also glimpse the brilliant star **Canopus**, the "False Cross" of stars from **Vela** and **Carina**, and maybe even the true Southern Cross, **Crux**, later in the night.

The winter Milky Way runs through Perseus and Auriga, between Orion and Gemini, and then between the two Dog Stars, Sirius and Procyon, until it reaches a section of Puppis which is thrust up into the area due east of Canis Major. Puppis contains some fine clusters and star fields for binoculars, but that is perhaps even more true of the constellation between the two dogs which the Milky Way pours over. Centered right in the Winter Triangle, its name is **Monoceros** the Unicorn.

Monoceros contains no stars brighter than fourth magnitude, but is a wonderfully rich region with even the slightest optical aid. As a matter of fact, one of its most interesting clusters is easily visible to the naked eye in dark skies. **NGC-2244** lies just east of the most southerly star in a northeast-to-southwest line that marks the head of Monoceros (it also forms part of the Arabs' long-forgotten Bow of Orion). The cluster is surrounded by the Rosette Nebula, which under excellent conditions can be glimpsed in small telescopes.

The Rosette is a hotbed of starbirth, just like its more spectacular counterpart, the Great Orion Nebula. Because of their great distances, both of these regions seem frozen in time and space, but the action in these giant fluorescent clouds has produced changes — visible to the naked eye — within the short tenure of human existence on Earth. Centered roughly on this area, the **Orion OB-1** association is an ancient cluster of hot O- and B-type stars that has broken up as it traveled around the Galaxy. Many supernovae have occurred in this group of stars; at least three times during the last five million years stars have exploded and sent their companions flying off like projectiles to their present constellations. These famous "runaway stars" are **AE Aurigae**, **53 Arietis**, and **Mu (μ) Columbae** — all just visible to the naked eye in dark skies. An ancient supernova also expelled the cloud whose outward edge now can be seen in long-exposure photographs of Orion as **Barnard's Loop**, which forms an incomplete circle about the Belt and Sword of Orion.



The region of Orion and its faint neighbor Monoceros is filled with nebulous gas, associated stars, star clusters, and other celestial showpieces. In taking this photo of the area, Steven J. Simmerman used a 50mm f/2 lens, hypersensitized 2415 film, a #92 red filter, and a 15-minute exposure. The Rosette Nebula shows as a bright circular glow at upper left.

Skylore

Few people who care about myths and lore would deny the unicorn his place in the heavens as a constellation. This creature of fantastic species has been known since ancient times, though its constellation came into being much more recently. The origin of the constellation Monoceros remains somewhat uncertain, just like the origins of the unicorn itself.

For a long time, the seventeenth-century German astronomer Jacob Bartsch was considered the creator of Monoceros, but in his *Astronomical Companion*, Guy Ottewell lists the Dutch geographer Petrus Plancius as the first known to have mentioned it. This leaves open the possibility of a still earlier creation by someone completely different. Plancius lived from 1552 to 1622 and is also credited by some with the invention of Camelopardalis, and by others with the invention of Columba. In any case, the existence of something like Monoceros before the time of Plancius was asserted long ago by Christian Ideler, who cited a reference from a work of 1564 to "the other Horse south of the Twins and the Crab." Author R.H. Allen also mentions that Joseph Scaliger found the constellation on a Persian sphere, presumably dating from still farther back.

It is not surprising that the unicorn finally received a constellation in the Middle Ages, since stories about the creature became very popular in those times. The unicorn is, however, derived from a far earlier part of history. The first known reference to the creature is by the Greek historian and physician Ctesias, who wrote around 400 B.C. that in India there was a kind of wild ass that had a white coat, purple head, blue eyes, and a single horn in the middle of its forehead that was white at the base, black in the middle, and red at the tip.

Hundreds of years later, Pliny had more to say about the unicorn. He stated that the unicorn is the fiercest of all animals, has a deep bellow, and is impossible to capture. According to him, the unicorn's body is like a horse's, its head like a deer's, its feet like an elephant's, its tail like a boar's, and its single black horn is two cubits (probably about three feet) long.

Where did the Greeks get the idea of the unicorn? Readers of the King James version of the Bible may recall a number of references to unicorns in the Old Testament, usually alluding to the animal's strength. The book of the Old Testament with the most interesting astronomical allusions is probably Job, where we find, *"Will the unicorn be willing to serve thee*, or abide by thy crib?"

The word "unicorn" in these cases is, however, a translation of the Hebrew word *re'em* made in the first Greek translation of the Bible, the Septuagint (third century B.C.). The *re'em* was the wild ox or aurochs, which was the ancestor of today's domesticated cattle. Aurochs were powerful, dangerous beasts, similar to today's Asian buffalos; they managed to survive in sparse numbers into modern times, but are now extinct.

In his *Guide to the Bible*, Isaac Asimov points out that Deuteronomy 33:17 mentions "the horns of unicorns" in the King James Version. The *re'em* is singular in the Hebrew original, however, so that the translation should be "the horns of the unicorn" (if the *re'em* were a unicorn — the Revised Standard Version translates *re'em* as "wild ox"). Why then did the scholars who made the Septuagint identify this creature with the legendary unicorn (which is Latin for "one-horn")? We'll investigate that question, along with a discussion of the narwhal and the Chinese unicorn, next month.

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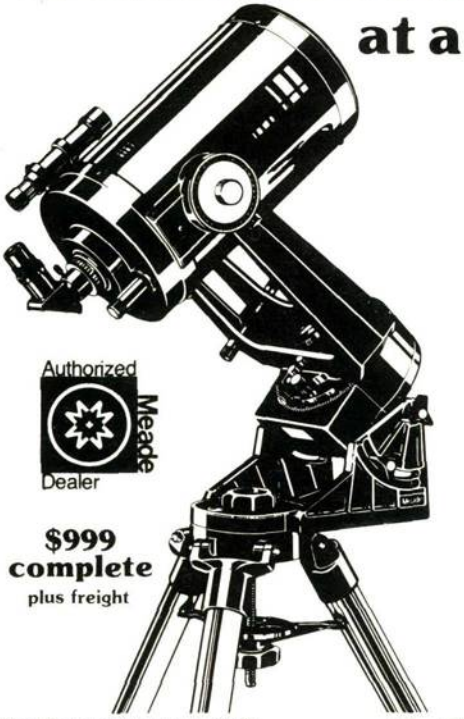

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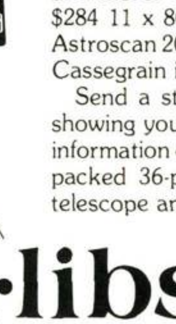

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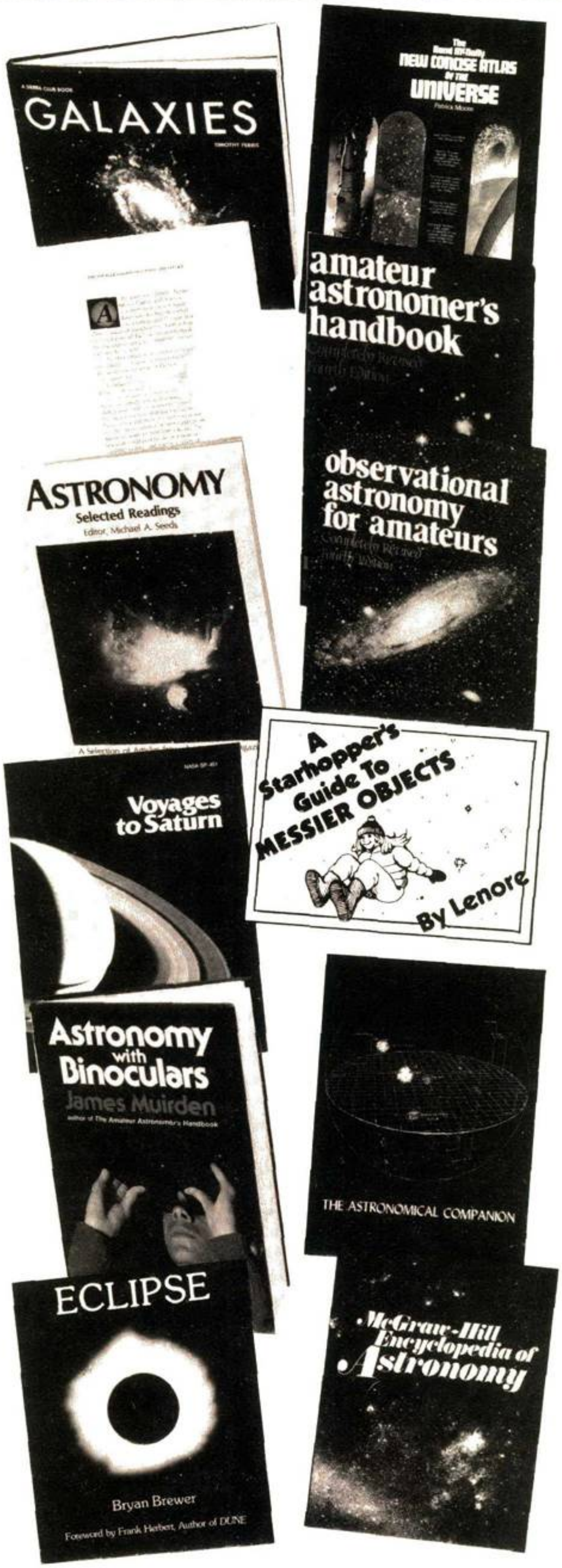
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TP 135-36
400
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1000
12

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Measuring the Shape of an Asteroid

by
Paul Maley

They used to be rare phenomena — but rare only in the sense that no one knew about them in advance. Today, astronomers who compute the orbits of minor planets are happy to provide detailed predictions for these once-thought-to-be-rare occasions when an asteroid passes in front of a star.

Why does anyone make this effort? Because occultations are the most accurate way to measure the size and shape of an asteroid. If the events are known in advance, they can be observed, and our knowledge of solar system bodies will grow.

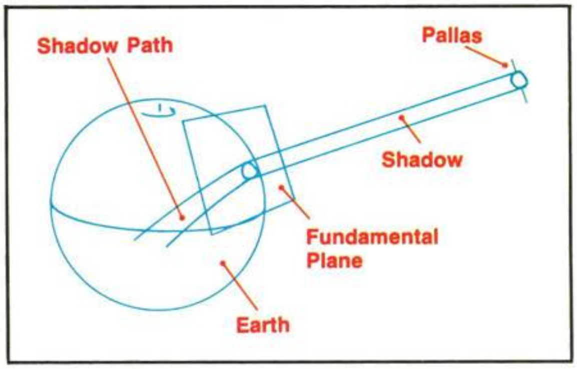
Such was the case with the occultation of the 4.7 magnitude star 1 Vulpeculae by the asteroid Pallas, the second largest minor planet in the solar system. Calculations showed that the path of visibility would cross North America and, therefore, potentially lie within the reach of the largest concentration of amateur astronomers in the world.

The International Occultation Timing Association, centered in Silver Spring, Maryland, undertook to organize a network of skilled amateur and professional astronomers across the United States. The initial prediction was not accurate enough to pinpoint exactly *where* in North America the shadow of Pallas would fall, so the planners had to be ready for an occultation path anywhere between Mexico and Canada.

An observer located within the shadow of the asteroid (cast onto the Earth by the star) will see the asteroid approach the star for several nights. Shortly before occulting the star, the asteroid image will merge with the star image, then suddenly the star will blink out as the shadow of the asteroid crosses the observer. A few seconds or minutes later, the star will blink on again. By timing the exact moments of blink-off and blink-on, astronomers can calculate the size of the shadow.

Since the shadow size is directly proportional to that of the minor planet, measuring the shadow gives a measure of the size of the asteroid. Because asteroids are bodies with little or no atmosphere, the eclipse of a star by such an object produces a sharp cutoff of starlight, rather than the gradual dimming that occurs when a planet with an atmosphere occults a star. Astronomers use a variety of equipment, ranging from binoculars and digital watches to telescopes with photoelectric photometers and computerized data-logging, to time the exact moment of the star's disappearance and re-emergence from behind the asteroid.

The size and form of an occulting asteroid can be determined with great accuracy only if enough timings are made from different stations along the shadow's track on Earth. To find the shape of the shadow, hence the shape of the asteroid, the coordinates of each station are projected onto a fundamental plane passing through the center of the Earth and perpendicular to a line between the center of the Earth and the asteroid. The observations are then fit to a circle or an ellipse.



An asteroid casts a "shadow" on Earth when it passes in front of a star. By timing the beginning and end of the occultation, it's possible to measure the shape of the shadow and thereby the shape of the asteroid. During the May occultation, Pallas' equator was tipped 20° to the Earth-star line.

The Pallas occultation was a significant event in the history of amateur participation in astronomical observation. Prior to the 1983 occultation of Pallas, the largest number of timings of a single asteroid occultation was 20, with an average of 3 per event. For this event, there were 130 timings!

Preparing for Pallas

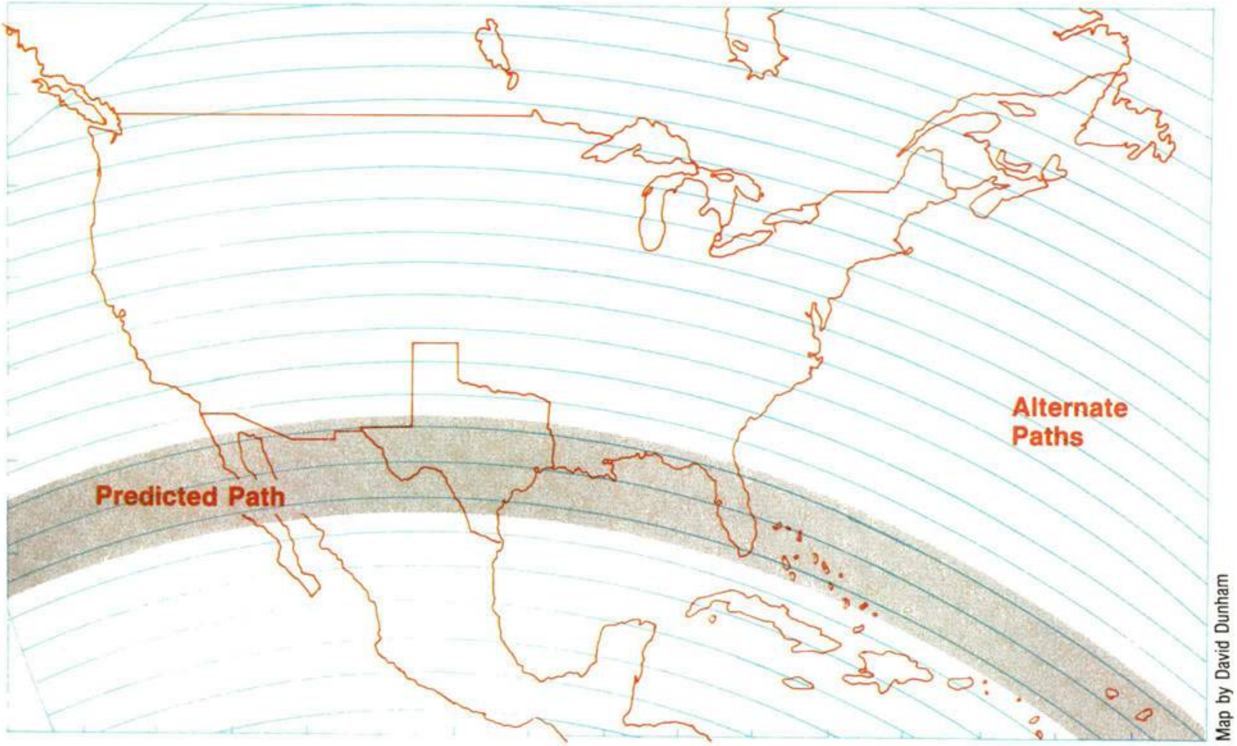
The Pallas occultation was identified as part of an ongoing search at the Royal Greenwich Observatory. The date predicted was a holiday weekend in the United States; the asteroid's 330-mile-wide shadow would pass over Arizona, New Mexico, Texas, Louisiana, Mississippi, Alabama, and Florida.

IOTA's effort, organized by the author and Dr. David Dunham, began in June 1982. A group of regional coordinators with IOTA were assigned as follows: B. Roberts — Alabama, Arkansas, Louisiana, Mississippi; P. Maley — Texas, Oklahoma; P. Manly — Arizona, New Mexico; R. Nolthenius and J. McMahon — California; G. Mallen and P. Pismis — Mexico; and H. Povenmire — Florida, Georgia. These coordinators located participants living in their areas.

Many more observers were alerted by a notice in the May 1983 issue of ASTRONOMY. In addition, IOTA arranged for last-minute predictions to be broadcast nationwide beginning one week before the event over the radio time signal station WWV. Through the courtesy of the National Bureau of Standards, these announcements were heard all over North America.

In most areas, observing sites were set up along east-west lines parallel to the shadow's path. In Texas, observers were positioned every 2½ miles to blanket the path with high resolution. This plan allowed for permanent telescope locations

Pallas: The Predicted Occultation Path



The shadow of Pallas crossed Florida, the Gulf states, Texas, Mexico, southern New Mexico and Arizona, and Baja California in about four minutes.

(at McDonald Observatory and Stephen F. Austin University) but could also accommodate numerous amateur groups such as the Houston Astronomical Society and the General Dynamics Astronomy Club of Fort Worth, Texas.

Mobile individuals were assigned "floating locations," which permitted each observer to set up anywhere on his line. The line was mapped for a hundred miles, allowing the observer to avoid threatening cloud formations. The system proved its worth. Several days before May 29, a hurricane formed off the coast of Mexico, spawning cloud cover across Mexico, Texas, and Louisiana. In Texas, the boundary of the solid cloud cover extended from Del Rio to San Antonio to Houston, and broken to solid cloud cover extended north and east more than 150 miles. None the less, observers in the Texas area — armed with line maps — fanned out on the afternoon of May 28 in a coordinated effort to find where the clear skies were.

Many participants were new to occultation observing. To help those living near Houston, IOTA sponsored a training session. Observers were ushered through a simulated occultation: A star field photo and an artificial star were projected together in a dark room. The star was then turned on and off while trainees practiced timing it.

The Observers and Their Sites

The smallest instruments used for the Pallas occultation were 7 x 35 binoculars; the largest amateur telescope was of 16-inch aperture. Despite a Full Moon, the star, 1 Vulpeculae, was clearly visible even in binoculars. After the star was occulted, the 10th magnitude asteroid remained visible to observers with 6-inch or larger instruments, but became invisible to binocular holders.

Many observers mentioned a gradual or stepwise disappearance and/or reappearance that took between half and three-fourths of a second to complete. At least three observers reported a momentary brightening just before the star was occulted. These phenomena were seen because it is a close binary star system.

Professional astronomers made photoelectric strip chart recordings with the 18-inch reflector at Stephen F. Austin University, the 16-inch 2-channel photometer at the University of Texas, and the 30-inch and 36-inch telescopes at McDonald Observatory. The chart records confirm the "step" in the star's drop in brightness seen by visual observers.

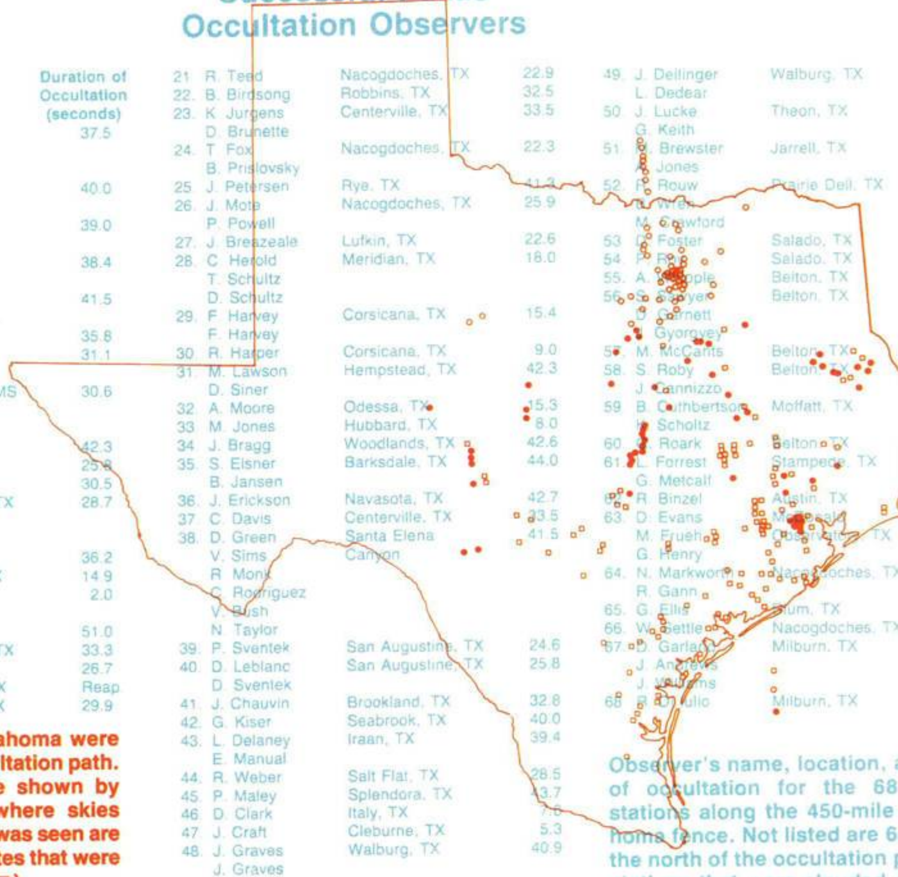
The Texas/Oklahoma effort is an example of the social diversity that permeates amateur astronomy. Mobile observing teams consisted of policemen, computer programmers, chemical engineers, aerospace engineers, pilots, uniform salesmen, plant managers, oil field workers, researchers, newsmen, photographers, students, printers, medical doctors, mechanics, planetarium instructors, insurance salesmen, plumbers, teachers, real estate agents, accountants, Air Force personnel, and others. In addition, three members of the Space Shuttle astronaut corps observed.

Observing locations were usually chosen at well-marked road intersections, but also included cemeteries, farms, schools, and airports. Sites had to be locatable on large-scale maps, so that we could determine the longitude and latitude of the observation reliably.

Members of the largest observing net spread across central Texas and southern Oklahoma, spanning the expected occultation path. The number of far southern observers was small due to the certainty of cloudy skies. Although the original line assignments placed observers roughly north-south of each other, because of the hurricane, many observers moved either east or west along their lines, seeking clear skies.

IOTA's planning worked well, but even the best plans couldn't control the weather. Observers on the San Antonio-Houston line experienced particularly perverse skies — they had locally clear skies either immediately preceding or following the occultation!

Successful Pallas Occultation Observers



	Name	Location	Duration of Occultation (seconds)
1.	E. Kolarich Bartz Hoke	Junction, TX	37.5
2.	B. Snow D. Hensch	Menard, TX	40.0
3.	A. New Garcia	Menard, TX	39.0
4.	R. Reeves Tatliger	Menard, TX	38.4
5.	T. Freeman V. Brady	Big Bend Nat. Park, TX	41.5
6.	G. Hoffler	Titusville, FL	35.8
7.	J. Stafford J. Camp	Odessa, TX	31.1
8.	J. Treadway R. Cates P. Lenart	Van Cleave, MS	30.6
9.	J. Young	Austin, TX	42.3
10.	J. Rose	Midland, TX	25.8
11.	J. Barton	Waco, TX	30.5
12.	B. Blagg J. Abdias P. Romig	Brownwood, TX	28.7
13.	R. Phillips	Leakey, TX	36.2
14.	T.R. Williams	Corsicana, TX	14.9
15.	B. Darnell B. Darnell	Athens, TX	2.0
16.	D. Baker	Conroe, TX	51.0
17.	K. Mace	San Angelo, TX	33.3
18.	C. Sexton	Mexia, TX	26.7
19.	A. Jones	Centerville, TX	Reap
20.	J. Culbertson	Jonesboro, TX	29.9
21.	R. Teed	Nacogdoches, TX	22.9
22.	B. Birdsong	Robbins, TX	32.5
23.	K. Jurgens D. Brunette	Centerville, TX	33.5
24.	T. Fox B. Prislovsky	Nacogdoches, TX	22.3
25.	J. Petersen	Rye, TX	41.3
26.	J. Mote P. Powell	Nacogdoches, TX	25.9
27.	J. Breazeale	Lufkin, TX	22.6
28.	C. Herold T. Schultz D. Schultz	Meridian, TX	18.0
29.	F. Harvey F. Harvey	Corsicana, TX	15.4
30.	R. Harper	Corsicana, TX	9.0
31.	M. Lawson D. Siner	Hempstead, TX	42.3
32.	A. Moore	Odessa, TX	15.3
33.	M. Jones	Hubbard, TX	8.0
34.	J. Bragg	Woodlands, TX	42.6
35.	S. Elsner B. Jansen	Barksdale, TX	44.0
36.	J. Erickson	Navasota, TX	42.7
37.	C. Davis	Centerville, TX	33.5
38.	D. Green V. Sims R. Monk C. Rodriguez V. Bush N. Taylor	Santa Elena Canyon	41.5
39.	P. Sventek	San Augustine, TX	24.6
40.	D. Leblanc D. Sventek	San Augustine, TX	25.8
41.	J. Chauvin	Brookland, TX	32.8
42.	G. Kiser	Seabrook, TX	40.0
43.	L. Delaney E. Manual	Iraan, TX	39.4
44.	R. Weber	Salt Flat, TX	28.5
45.	P. Maley	Splendora, TX	43.7
46.	D. Clark	Italy, TX	7.6
47.	J. Craft	Cleburne, TX	5.3
48.	J. Graves J. Graves	Walburg, TX	40.9
49.	J. Dellinger L. Dedear	Walburg, TX	40.5
50.	J. Lucke G. Keith	Theon, TX	40.2
51.	R. Brewster A. Jones	Jarrell, TX	39.5
52.	R. Rouw L. Wren M. Crawford	Prairie Dell, TX	39.7
53.	D. Foster	Salado, TX	36.8
54.	P. [illegible]	Salado, TX	38.0
55.	A. Whipple	Belton, TX	37.6
56.	S. Sawyer D. Garnett J. Gyorgyey	Belton, TX	36.9
57.	M. McCants	Belton, TX	36.1
58.	S. Roby J. Cannizzo	Belton, TX	35.6
59.	B. Cuthbertson H. Scholtz	Moffatt, TX	34.7
60.	[illegible] Roark	Belton, TX	34.0
61.	L. Forrest G. Metcalf	Stampede, TX	33.9
62.	R. Binzel	Austin, TX	40.2
63.	D. Evans M. Frueh G. Henry	McDonald Observatory, TX	42.0
64.	N. Markworth R. Gann	Nacogdoches, TX	21.0
65.	G. Ellis	Blum, TX	10.1
66.	W. Settle	Nacogdoches, TX	28.6
67.	D. Garland J. Andrews J. Williams	Milburn, TX	33.5
68.	R. DiIulio	Milburn, TX	33.7

Observers in Texas and Oklahoma were spread across the entire occultation path. Successful observations are shown by solid dots (●). Locations where skies were clear but no occultation was seen are shown by open circles (○). Sites that were clouded out are shown by (☐).

Observer's name, location, and duration of occultation for the 68 successful stations along the 450-mile Texas/Oklahoma fence. Not listed are 65 stations to the north of the occultation path and 139 stations that were clouded out.

The large number of sites north of the northern limit reflects the completeness of the coverage IOTA wanted, as well as the extraordinary dedication shown by members of the Texas Astronomical Society, Denton Astronomical Society, and the Ardmore and Oklahoma City amateur astronomers — groups who observed even though they *knew* they were outside the final predicted shadow path.

Observations of the Occultation

The May 1983 Pallas occultation is the most widely observed eclipse of a star by a minor planet ever — though we hope future occultations will also be widely observed.

All told, the efforts of the hundreds of observers produced the following state by state yield of successful observations:

Texas	68
Florida	40
Arizona	6
Baja California	4
Mississippi	2
Louisiana	3
Mexico	1

Those observations consisted of 115 visual timings, 4 recordings made with video camera, and 11 photoelectric records.

Despite their size, these numbers still do not reflect the true magnitude of the effort. A much larger number of observers *attempted* to observe the occultation but were frustrated by clouds or were stationed outside the shadow path of Pallas.

	Total	Clouds	Outside
Texas/Oklahoma	262	139	65
Arizona/New Mexico	82	61	15
Louisiana/Mississippi	18	5	9
California	28	16	12
Florida	80	—	—
Others	24	—	—
Totals	**494**	**221**	**101**

(A dash indicates that statistics were not available at the time this article was written.)

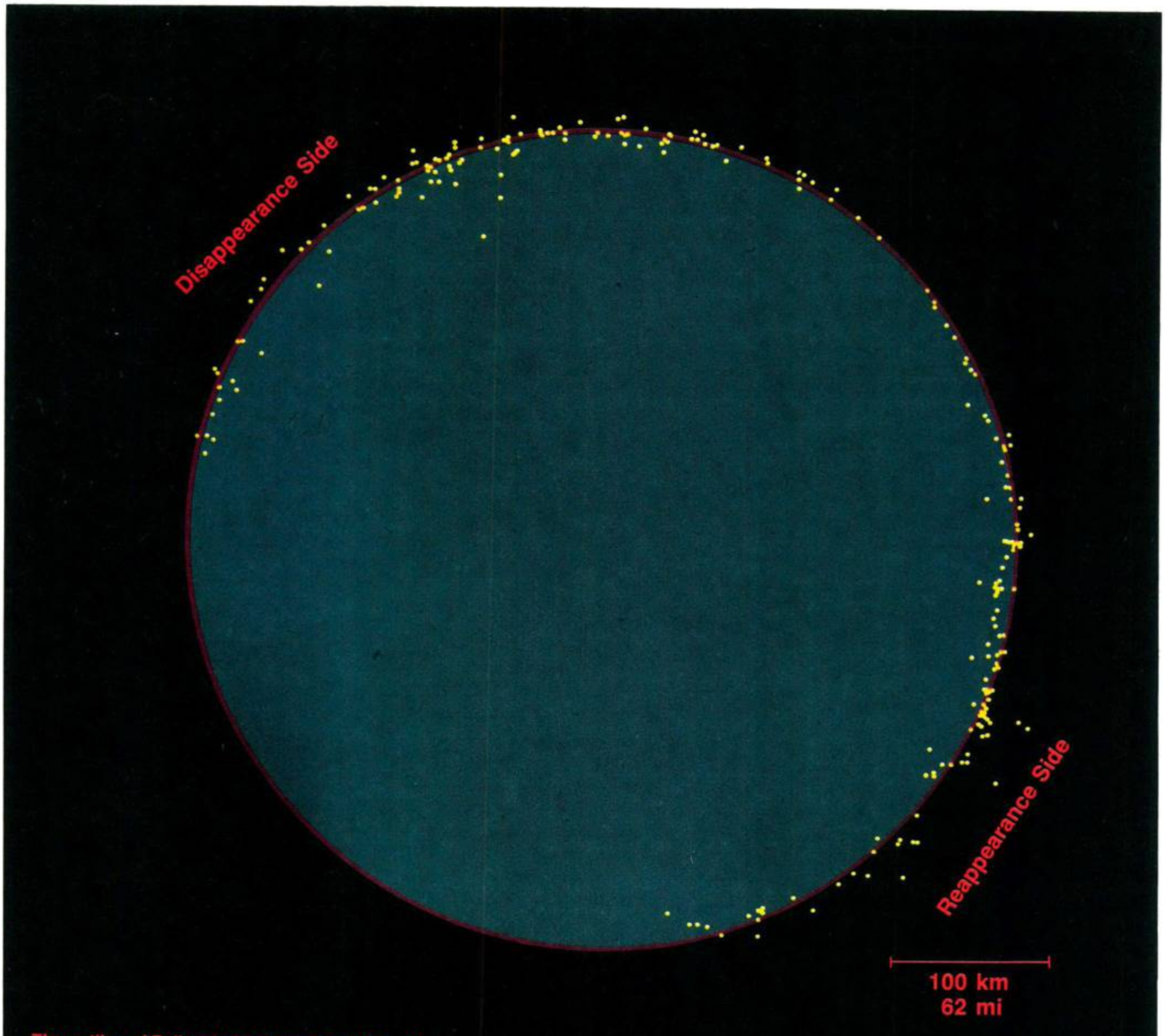
We used two standardized timing techniques. Observers with portable short-wave radio gear tape recorded WWV time signals and marked the times of disappearance and reappearance by voice. Observers without short-wave radio gear calibrated their digital watches before and after the event. Accuracy with this calibrated watch technique was plus or minus one second at worst case and better for many observers. Most observers saw the star occulted for 30 to 40 seconds; the longest occultation lasted 44 seconds.

Special care was given to observing secondary occultations by possible satellites of Pallas before and after the predicted occultation time for the asteroid itself. Fewer than a dozen reports of suspected disappearances were catalogued, and all were discounted by the observers themselves or by close comparison with adjacent observers' records. In most cases, these reports came from inexperienced observers, although several recorded on video tape were slow fadeouts indicative of clouds. Based on data compiled so far, there is no evidence for satellites of Pallas.

Bill Darnell of Houston established the northernmost observation of the occultation from a point near Athens, Texas. Darnell saw a two-second outage with an 8-inch telescope. He detected a flicker just as 1 Vulpeculae began a 1.0-second fade to invisibility. Observers north of Darnell saw no occultation.

The southernmost observation was made by B. Riefer at Burns Lake, Florida, of an outage lasting 35 seconds. Because of clouds and geography, there were no observers near the southern limit.

Two dedicated observers crisscrossed several hundred miles, dodging cloud masses, in an effort to find clear sky, but were clouded out at the last moment. Another traveled over 100 miles from the



The outline of Pallas derived from the IOTA effort shown here projected on the fundamental plane. The line represents the preliminary elliptical outline derived, and individual timings are shown as points.

center of the path to the southern limit; then, because of the weather, drove an additional 300 miles to finally find clear skies near the northern limit of the occultation.

Results

The preliminary profile of Pallas, as silhouetted on the fundamental plane, is an ellipse roughly 520 kilometers long and 516 kilometers wide. Approximately 80% of Pallas' limb was observed. The asteroid displays no large asymmetries or irregularities that can immediately be identified, although smaller dips in the profile suggest possible limb topography.

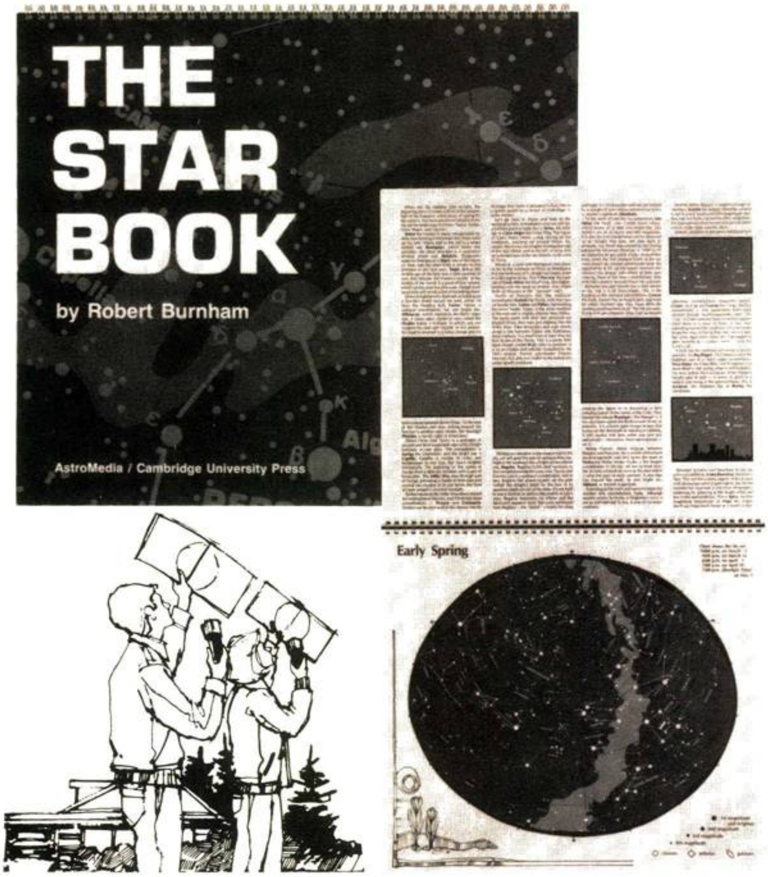
Some of the scatter in the observations is due, no doubt, to reaction time errors of the observers. Furthermore, some timings have obvious problems since they differ from the norm. These will be investigated individually. The southern segment of Pallas went unobserved due to the extensive clouds in that part of the occultation path.

A preliminary reduction of the photoelectric and video observations (i.e., those not subject to human error in judging the moment of occultation) shows a diameter for Pallas of 522 kilometers, with a flattening in the averaged ellipse of 3.7 kilometers. When the visual timings are processed along with the instrumental data, the solution is 516 kilometers with a flattening of about 4.4 kilometers. This shows that the results obtained by simple visual methods differed from the impartial high-tech methods by only about one percent!

A more detailed analysis of the 1983 Pallas occultation by astronomers at Lowell Observatory and the U.S. Naval Observatory is now under way. It is significant that amateur astronomers contributed more than 90% of all the data obtained, even though human reaction times skewed the observations to a small degree. However, the amateur timings, taken together, form a valuable baseline for Pallas shape analysis.

Before 1977, only seven asteroid occultations had ever been observed. In the six years since, that number has increased sixfold. Further observation of these important events will continue to provide clues into the diameters and shapes of these distant bodies.

Paul Maley was co-organizer of Texas Pallas observations for IOTA.



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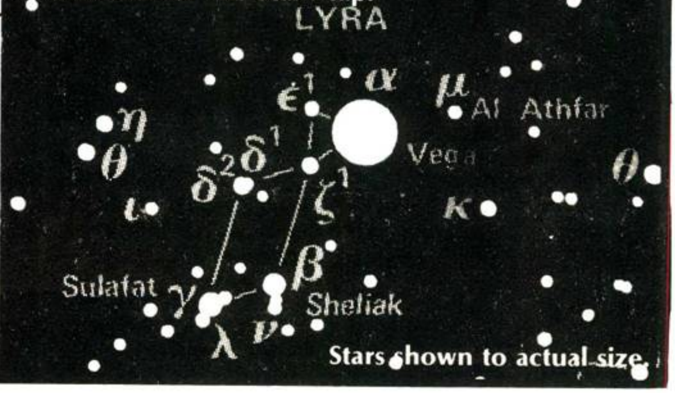

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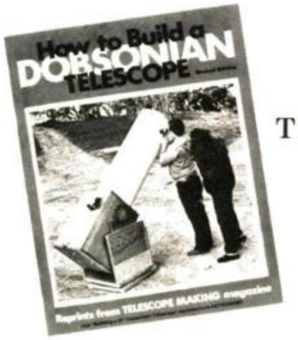

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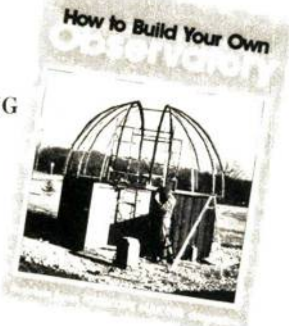

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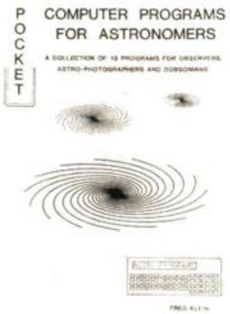

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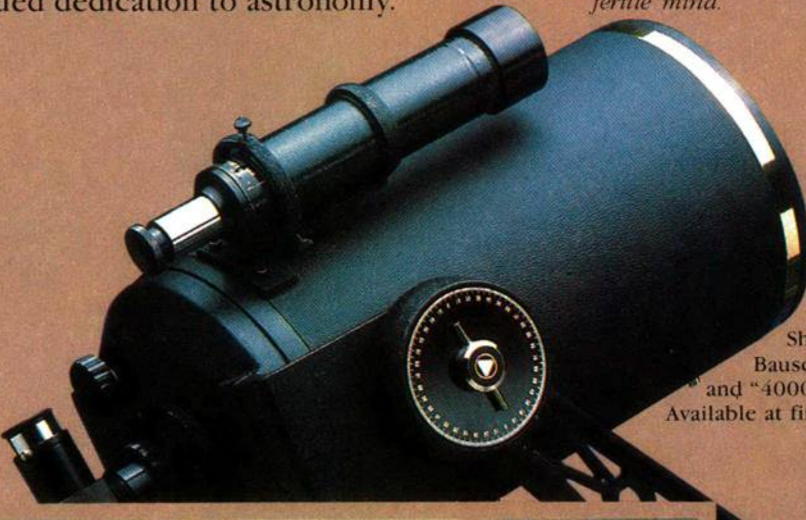

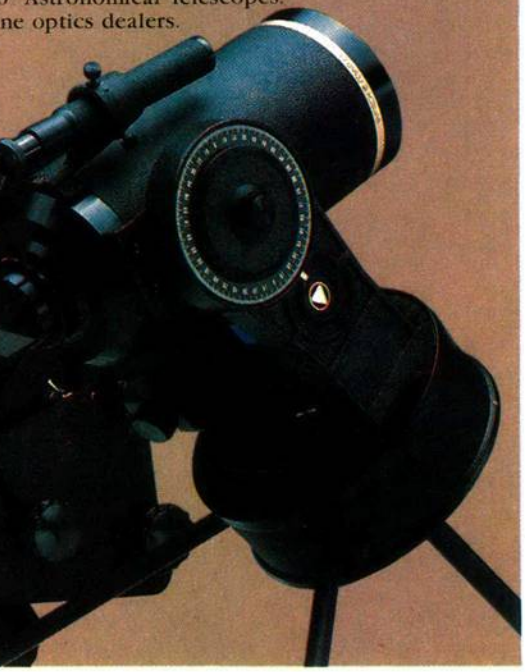

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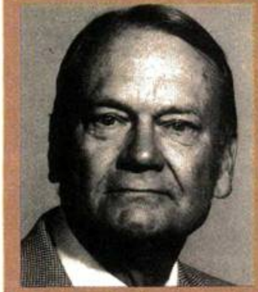
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Halley Studies from the Shuttle

A group of NASA scientists and engineers have been developing a payload for the Shuttle called "Astro." It is a collection of telescopes and cameras designed to work at ultraviolet wavelengths. The Astro program as a whole consists of three flights, during which the instruments will examine solar system objects, stars, nebulae, the interstellar medium, galaxies, and quasars.

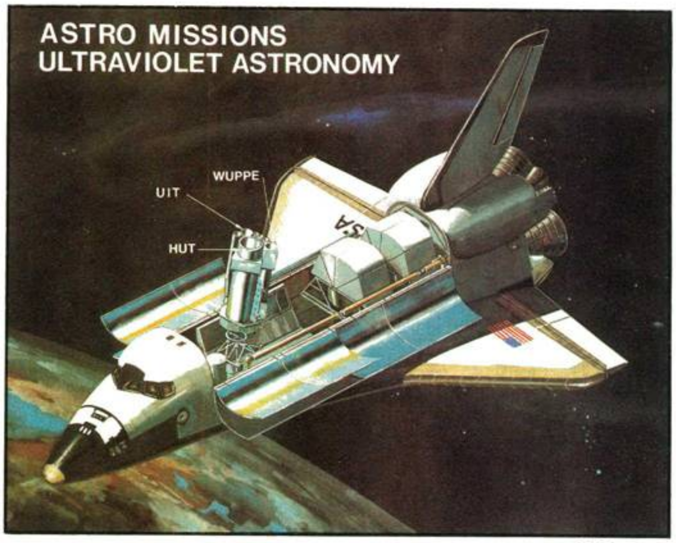
But it so happens that the first of these flights is scheduled to be launched in March 1986 — just when Comet Halley will be passing by. Accordingly, the flight planners have made some changes in the basic astronomy program that will allow the instruments to examine the comet and take wide-field pictures, make UV spectral polarimetry measurements, and do UV spectroscopy.

The main instruments in the Astro package are the HUT, the UIT, and the WUPPE — acronyms for the Hopkins Ultraviolet Telescope, the Ultraviolet Imaging Telescope, and the Wisconsin Ultraviolet Photo-Polarimetry Experiment. The HUT is a 90-centimeter aperture, f/2 telescope designed to observe in the 425 to 1850 Angstrom wavelength band, with special sensitivity in the 850 A to 1850 A range. Its detector is a spectrograph placed at the prime focus.

The UIT is a 38-cm, f/9 Ritchey-Chretien Cassegrain designed to take pictures in the 1250 A to 2800 A region of the spectrum. Its resolution is 2 seconds of arc, and the angular diameter of its field of view is 40 minutes of arc — a little larger than the apparent diameter of the Moon. It should be able to see O-type stars as faint as +25.3 magnitude.

The WUPPE is a 50-cm, f/10 Cassegrain telescope that collects light for the ultraviolet spectropolarimeter. The scope can observe between 1400 A and 3200 A and has an average angular resolution of about a second of arc (though the resolution of the spectrometer itself is somewhat coarser).

Besides these instruments, two wide-field cameras will also be aboard the first Astro flight. These will be modified 35mm camera bodies, equipped with large film magazines and using (probably) 85mm or 50mm lenses, backed with image intensifiers and special filters. One camera will be dedicated to observing dust features in the 5000 A to 6500 A (orange to red) region of the spectrum; the other will observe plasma activity in the 3800 A to 5000 A (blue to orange) region.



NASA photo

The scientists plan to devote Astro's first flight to Halley "as frequently as [is] scientifically justified" and will coordinate their work with other national and international Halley-watching programs.

NASA's Comet Halley Encounters

Though poor in dollars, NASA's planetary program is rich in ideas. Despite budget cuts that resulted in the cancellation of its ambitious Halley's Comet mission, NASA may be able to put a second spacecraft out there to observe the famous comet's return in 1986.

NASA's first craft will be the third International Sun-Earth Explorer (ISEE-3), a satellite launched in 1978 to monitor the solar wind near Earth. By means of a complex series of orbital maneuvers using the Moon (see ASTRONOMY, September, page 20), the craft will be sent into solar orbit where it will encounter Halley's Comet twice, in October 1985 (at 138 million kilometers) and March 1986 (31 million km).

The second craft NASA scientists plan to use is Pioneer Venus, which has been orbiting that planet since late 1978. Through a fortunate set of circumstances, Pioneer Venus will be in excellent position to observe Halley's Comet. And while it was not designed for comet studies, at least one instrument aboard the orbiter can provide scientists with valuable information.

The spacecraft will be able to study Halley's Comet because of the position of Venus relative to the comet's orbit. Venus, and therefore the orbiter, will pass within 40 million km of the comet just five days before its perihelion on February 9, 1986. The space probes launched by the European Space Agency, Japan, and the Soviet Union will all pass much closer to the comet, but these probes will encounter the comet in March, a month or more after perihelion.

The best time to study Halley's Comet (or any comet, for that matter) is just before, during, and after perihelion, according to Ian Stewart of the University of Colorado at Boulder. During this phase of a comet's orbit, Stewart explained, material from the nucleus evaporates at the highest rate.

Because of the distances involved, most of the instruments aboard the orbiter, such as the radar mapper and the 3.7-centimeter telescope, will be virtually useless for studying the comet. NASA scientists will rely almost wholly on the orbiter's airglow ultraviolet spectrometer for observing the comet. Stewart, who is one of the principal investigators for the Pioneer Venus project, said the UV spectrometer can provide important data about the material in the nucleus — including oxygen, hydrogen, and carbon — which will evaporate when the comet heats up. The spectrometer will measure evaporation rates and quantities as well as observe any sudden outbursts of material that may occur as the comet's temperature peaks.

NASA has not yet formally decided to use Pioneer Venus to study Halley's Comet. But Stewart is confident that NASA will eventually give the go-ahead for the project, which is currently, and unofficially, being referred to as the "Halley Encounter."

One reason for Stewart's confidence is that the Halley Encounter project will not require much, if any, additional funding. Turning the spacecraft so the spectrometer points toward the comet can be done as part of the orbiter's routine operations.

If there is any concern, it lies in scheduling tracking time with NASA's Deep Space Network, which monitors a number of spacecraft. The Voyager space probe will encounter Uranus two weeks before the proposed Halley Encounter. Careful rescheduling and plenty of planning should guarantee that the two projects do not conflict.
Robert G. Nichols.

1983 American Workshop on Cometary Astronomy

An announcement that Comet Halley will be at least two magnitudes brighter than previously calculated was made during the second American Workshop on Cometary Astronomy which was held at the Jet Propulsion Laboratory in Pasadena, California, on October 1. The workshop was co-sponsored by International Halley Watch (which operates out of JPL) and the *International Comet Quarterly*.

Stephen Edberg of JPL chaired the proceedings, and speakers included professionals Ray Newburn, Zdenek Sekanina, and Paul Weissman (all of JPL); and amateurs Alan Hale, John Sanford, Jack Marling, John Bortle, Charles Morris, and Dan Tidwell. The participants ranged from beginners to at least one comet discoverer — Don Machholz who captured Comet Machholz in 1978 — and the presentations varied accordingly. The more technical included a study of cometary nuclei by Sekanina, Newburn's discussion of cometary photoelectric photometric techniques, Marling's talk on filters, and Tidwell's on photographic materials.

Of wider interest were Weissman's discussion on the various spacecraft missions — not only to Halley but to other periodic comets in the mid-1990s — Edberg's on the International Halley Watch, Hale's, which detailed comets available for practicing techniques, and Sanford's survey of the history of cometary photography. In the afternoon, the major presentation was the "Morris & Bortle Show," during which just about every technique of visual comet observing and reporting was covered. It was at the conclusion of their two-hour multi-media discussion that Bortle announced that Halley will be at

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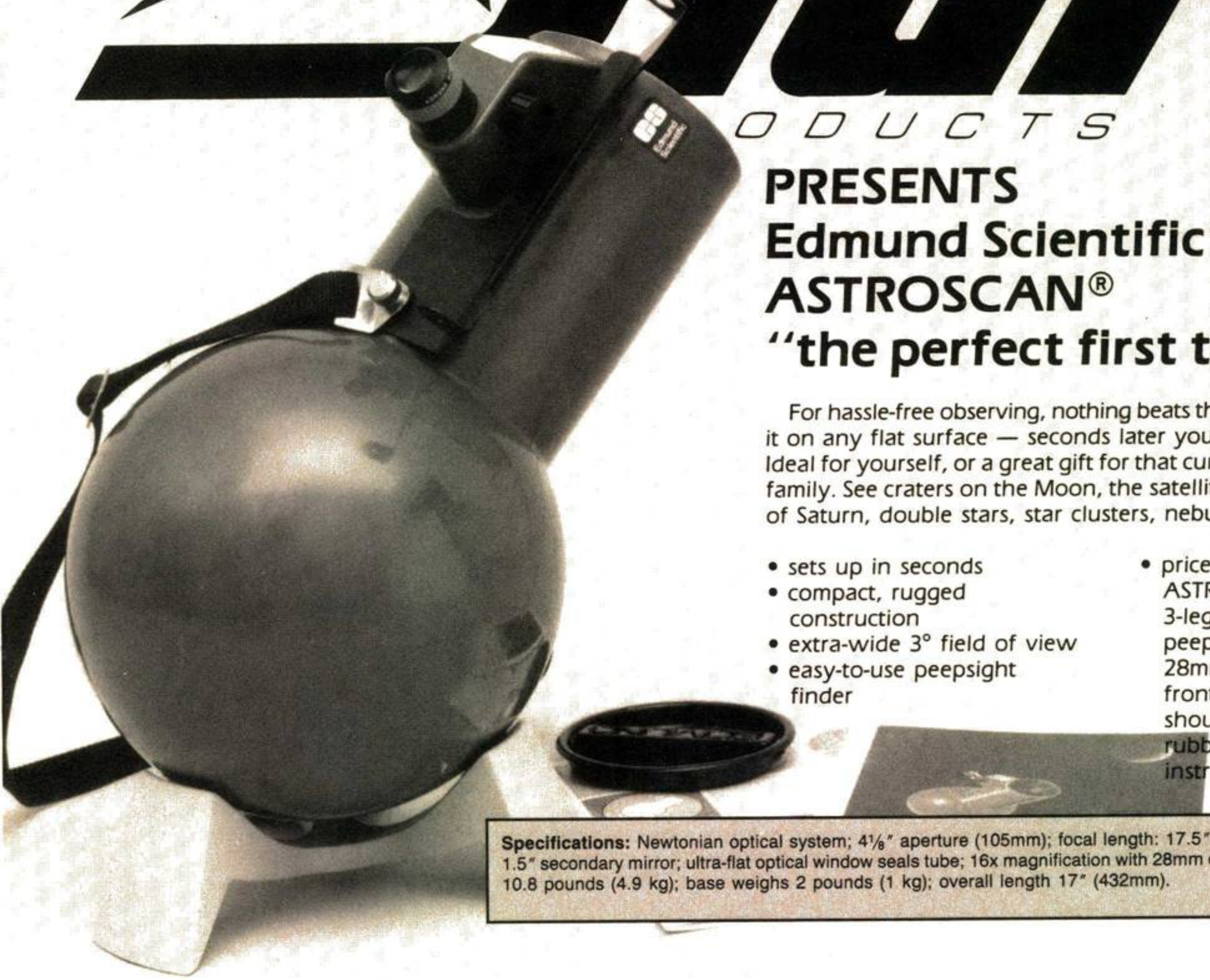

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least second magnitude in 1986 — and perhaps even first.

Bonuses for conference attendees were a multi-media film presentation entitled "Welcome to Space," which was a visual summary of America's efforts in exploring space, and a tour of the JPL Space Flight Operations Facility (the control center for all of NASA's unmanned space missions) — plus a guided look into the "clean room" where the spacecraft for the Galileo mission to Jupiter is being assembled. Since JPL no longer has regular monthly open house tours, this provided a rare opportunity to observe some of NASA's work.

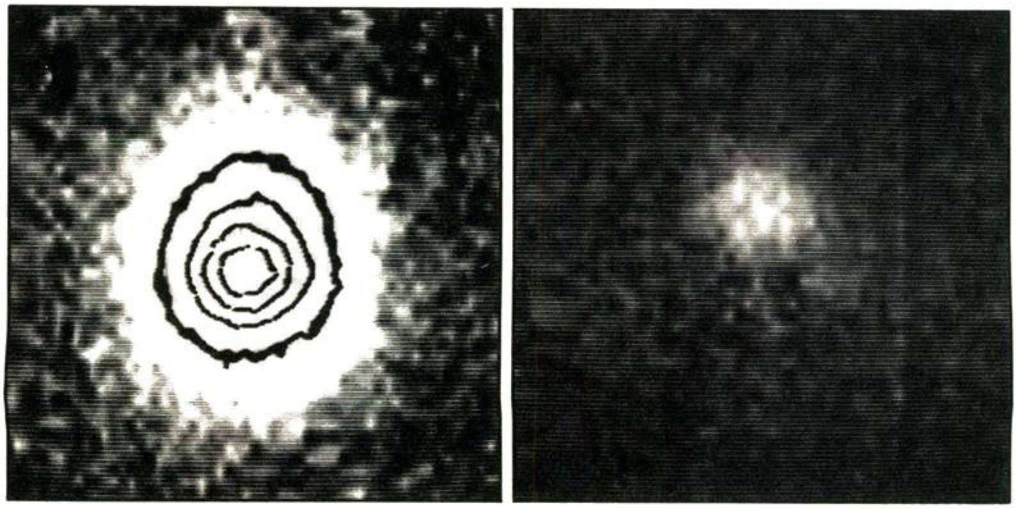
A hands-on practice session in the San Gabriel Mountains (home of Mt. Wilson Observatory) was scheduled for the evening, but the weather prevented it. As a substitute, some indoor practice was held.

Organizers have not yet decided if another such conference will be held in 1984. One has already been planned for June 1985 (in Tucson), however. Anyone interested should contact Stephen Edberg, Mail Stop T-1166, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109. *John & Stephanie Mood.*

Charon Photographed

Charon, the satellite of Pluto, was discovered in 1978 when James Christy of the U.S. Naval Observatory noticed that photographs of the planet showed an elongated image every 6.4 days. This matched Pluto's rotation period, and calculations soon showed that Pluto had a satellite that circled the planet at a distance of about 20,000 kilometers in a highly inclined orbit. But up until now, no images have been made of Charon alone.

Recently, however, H.J. Reitsema, F. Vilas, and B.A. Smith of the University of Arizona's Lunar and Planetary Laboratory (writing in *Icarus*) reported using a charge-coupled device and a 60-inch telescope to photograph Pluto and Charon. By digitally subtracting Pluto's image, they revealed the satellite itself; Pluto is 5.5 times brighter than Charon, and if the two are equally reflective, Charon's radius comes to 0.43 times that of Pluto.



Below: The combined image of Pluto and Charon shows its lopsided shape. Right: Charon alone. University of Arizona Observatories.

Soviet Space and Astronomy

The present political climate is indeed as cold and inhospitable as space, but the Soviet Union is nevertheless continuing to explore space from the ground as well as through regularly launched probes.

- Venus has come under the scrutiny of two new spacecraft, Veneras 15 and 16, which are now orbiting the planet. Venera 15, launched on June 2nd, is in an elongated elliptical orbit around the planet with a period of 24 hours. Communications with the spacecraft have found all to be well; it is now in the process of carrying out atmospheric analyses. Its partner, Venera 16, arrived on October 16th. Both craft will transmit more data about the planet that has preoccupied the Russians for a decade.

Previous Venera landers have succumbed quickly to the enormous pressures and corrosiveness of Venus' atmosphere; because of this, optical transmissions have been frustratingly brief. The Institute of Space Research at Frunze has attempted to combat the immediate effects of the 90+ atmospheres by designing a camera capable of withstanding a 600-foot drop onto concrete. The electrical discharge recorder, which collected a variety of information, also had to function under a temperature often exceeding 500° Celsius and a pressure peaking at a crushing 100 atmospheres.

- At present, deputy director Vyacheslav Balbanov of the Institute is involved in the design and construction of even more sophisticated instruments for future flights to Venus and Comet Halley. The Institute has also cooperated with the French by building the complex system of photometers used on the Soviet/French Aureole-3 satellite and the Earth resources detector "Fragment," which has been operating successfully for the past three years aboard the Meteor-Priroda satellite. Soviet/French collaboration has been further expanded by the development of a gamma-ray telescope that will be the largest instrument of its kind.

- Seeds raised in space during a mission aboard the space station Salyut-7 will be used to produce further plants in space in the near future. The experiment is necessary, says Adolfas Merkis (who designed the space "greenhouse"), to show that plants can indeed produce successive generations in weightless conditions. Researchers have already found that Earth-germinated seeds can produce new plants in space and that seeds born in space can also produce new seeds on Earth. Of great significance is whether seeds raised in space can produce new plants in space — plants that are not malformed.

Merkis believes that they will grow properly in space because no spaceship has complete weightlessness (this has been termed microgravity by some researchers); it could be that a "memory" of gravity is already genetically encoded in the plant. He expects that gravitational forces as low as 0.00001 G will be enough to "tell" a plant where to direct its roots and its leaves.

- Similarly, "Crocus," an experimental package devised by Soviet biologists to determine the general effects of a space environment on living plants, will also be flown aboard Salyut. So far, the only plant to have successfully matured has been an arabidopsis (a type of mustard) grown aboard Salyut-7 and brought back to Earth by Svetlana Savitskaya. There is still some doubt as to why and how arabidopsis succeeded when other plants failed, but it is believed that a cotton wool filter in the propagation unit might well have contributed to its success. Establishing the right conditions for the vegetable life-cycle in space is important both for the future of space flight and for the fundamental understanding of plant biology. It is an area that will make space stations on a large scale genuinely viable.

- Trees will also be vital to the well-being of a large space station. In the USSR's Central Botanical Gardens live some 20 Canadian spruce saplings grown from seeds given to Soviet cosmonauts during the Apollo/Soyuz mission. When Soyuz returned to Earth, the seeds were planted in the Central Botanical Gardens and subsequently developed strong shoots. In an adjoining plot, ordinary Canadian spruce seeds were planted as a control and, interestingly, have not grown with the same vigor as that displayed by their space-flown cousins. The space-flown spruce trees have now been transferred to the Kemerovo Department of Forestry to be kept under close scientific examination to determine whether space can offer fertility to our planet's most significant and vital plants.

- Five large telescopes operating in the 10-meter waveband are to be teamed to give an "observatory" thousands of kilometers in diameter. The coordinating center will be the large radio telescope near Kharkov which uses over 2,000 detectors arranged in a T-shape two kilometers long and one kilometer wide. This instrument will examine pulsars in greater detail. The whole intricate arrangement has already been used

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ASTRO NEWS

to scan most of the northern celestial hemisphere and has identified about 3,000 radio sources, including some found only in the 10-meter band.

The same telescope is also being used to investigate the star XY-2 in Orion, which is spewing forth massive quantities of matter. Discovered initially by the orbiting ultraviolet and X-ray telescope Astron, it appears that XY-2 is a hot supergiant with a diameter a hundred times that of our Sun and a surface temperature of 25,000° K. Astron has taken thousands of ultraviolet spectra of stars and galaxies, including a number of stars in Cancer containing large amounts of heavy elements.

- The Ukraine Institute of Radiophysics and Electronics is involved in research into the emission of radio waves from Jupiter. Situated at Kharkov, their 10-meter radio telescope has been instrumental in solving a puzzling enigma. Jupiter is the sky's most potent source of radio shortwaves, regular emissions of which are directly linked to its rotation and that of its moon, Io. Long-term observations have identified powerful bursts of radio transmission associated with lightning on a colossal scale.
- A very large optical telescope is planned by the Crimean Astrophysical Observatory. The new instrument will have a main mirror over 83 feet in diameter, compared to the 20-foot (6-meter) diameter of the Zelenchukskaya telescope in the Caucasus. The difficulties increase dramatically in casting, cooling, polishing, and supporting such a large mirror, particularly since the present Zelenchukskaya mirror was at the peak of Soviet technology when it was made.

The new telescope avoids these problems, in part by use of a mosaic of 500 hexagonal sections arranged to form a single huge mirror. This advantage is offset by having to use complex electronic control systems and because of the need to keep each of the segments in precise micro-alignment with every other segment. The telescope, including its supports, will weigh some 4,000 tons. To reduce gravitational flexure, the telescope will have an alt-azimuth mounting. *Aldo G. Rabaiotti.*

ASTRO CALENDAR

February 17-19	**"Astron" Exhibition/Congress,** Milan, Italy. Contact: Comis Lombardia, Via Boccaccio 7, 20123 Milan, Italy.
March 3	**Seminar in Electronics Oriented Astronomy,** Cypress College, Cypress, California. Sponsored by Orange County Astronomers. Contact (send SASE): Orange County Astronomers, 2215 Martha Ave., Orange, CA 92667. Phone John Sanford, (714) 639-8446 or Harry Miller, (714) 637-8870.
March 12-16	**Fifteenth Lunar and Planetary Science Conference** (professional meeting). Johnson Space Center, Houston, Texas. Contact: 15th LPSC, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058.
April 5-8	**National Meeting of the National Science Teachers Association,** Boston, Massachusetts. Contact: N.S.T.A., 1742 Connecticut Ave., Washington, DC 20009. Phone (202) 328-5800.
April 20-22	**Third Annual Conference on Space Development,** San Francisco, California. Sponsored by the L-5 Society. Contact: Charles Curley, Third Annual Conference on Space Development, 1275 Fourth St. #242, Santa Rosa, CA 95404. Phone (707) 538-1227.
May 5	**Astronomy Day.** For more information, contact: Gary Tomlinson, Astronomy Day Coordinator, Astronomical League, Chaffee Planetarium, 54 Jefferson S.E., Grand Rapids, MI 49503. Phone (616) 456-3985. The Astronomical Association of Northern California will be hosting Astronomy Day on April 7.
May 25-28	**Riverside Telescope Maker's Conference,** Big Bear, California. Contact: Cliff Holmes, 8642 Wells Ave., Riverside, CA 92505.
May 30-June 3	**Texas Star Party,** Fort Davis, Texas. Contact: TSP '84, Dept. A, 128 N. Commerce, Burleson, TX 76028.
July 7-12	**Joint Meeting of the Astronomical Society of the Pacific and the Western Amateur Astronomers,** University of California, Santa Cruz, California. Contact: Summer Meeting, A.S.P., 1290 24th Ave., San Francisco, CA 94122.
July 12-14	**Microcomputers in Astronomy II.** Fifth annual IAPPP-Fairborn Symposium, Fairborn, Ohio. Contact Russell M. Genet, Fairborn Observatory, 1247 Folk Rd., Fairborn, OH 45324.
July 28	**Stellafane,** Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Rd., Sudbury, MA 01776.
August	**Sixth World General Assembly of International Union of Amateur Astronomers.** Bologna, Italy. Contact: Dr. Luigi Baldinelli, c/o A.A.B., Casella Postale 1630 AD, 1-40100 Bologna BO, Italy.
August 1-4	**ALCON 84,** National Convention of the Astronomical League. Carroll College, Waukesha, Wisconsin. Hosted by Milwaukee Astronomical Society. Contact: ALCON 84, P.O. Box 725, Mequon, WI 53092.
August 6-10	**Spitz Space Systems' Summer Institute in Planetarium Education,** Chadds Ford, Pennsylvania. Contact: 1984 Planetarium Summer Institute, Spitz Space Systems, Inc., Route One, Chadds Ford, PA 19317.
August 17-18	**Near-IR and Solid-State Photometry Symposium,** Lowell, Michigan. Hosted by IAPPP and Optec. Contact: Russell M. Genet, Fairborn Observatory, 1247 Folk Rd., Fairborn, OH 45324.

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ANNOUNCEMENT — The Earth/Space Astronomy Club prints a monthly newsletter called "Astro-News," giving up-to-date information on space. Our members also receive a discount from two prominent distributors of astronomical items. We are especially interested in other astronomers' observations of major asteroids and planets. Contact Billy Casebeer, President, Earth/Space Astronomy Club, P.O. Box 372, Oologah, OK 74053.

ANNOUNCEMENT — The Active Amateur Astronomers of Maryland will hold monthly meetings at the Hamilton Branch of the Enoch Pratt Library System in Baltimore on the following dates: January 18, February 22, March 21, April 18, June 20, and July 18. Meetings run from 6:30 to 8:30; the date of the May meeting will be determined later. Contact Robert Calhoon, P.O. Box 397, Chestertown, MD 21620, phone (301) 778-4809; or Doug Cook, 8072 Green Bud Lane, Apt. T-4, Glen Burnie, MD 21061, phone (301) 962-1622.

ANNOUNCEMENT — The South Shore Astronomical Society, Norwell, Massachusetts, cordially invites the public to attend our monthly meetings. The dates and times of these meetings can be obtained from the corresponding secretary, Rolf Egon, at (617) 337-4279 after 7 p.m.

ANNOUNCEMENT — The Kalamazoo Astronomical Society meets on the first Friday of each month at 7 p.m. at the Hans Baldauf Planetarium in the Kalamazoo Museum, 315 S. Rose. The general public is invited to attend. Contact Joe Kemmerling at (616) 746-4993 or Joe Medsker at (616) 375-3579.

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WANTED — Newly-formed amateur astronomy club wishes to exchange club newsletters on a regular basis. Contact Ken White, 3405 Cherry, Texarkana, AR 75502.

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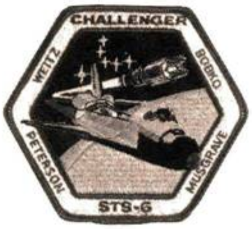

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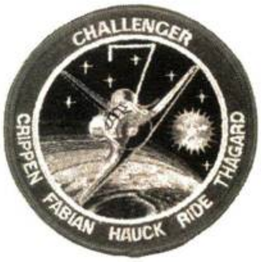

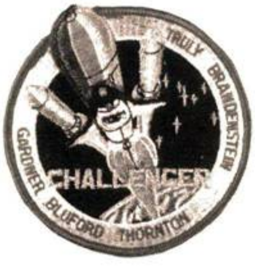

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POSSIBLE PLANETS
PART II

BY STEPHEN L. GILLETT

Last month, in Part One, we reviewed the major forces affecting the nature of a planet's surface. Now that we've identified these processes, we can look at the planetary possibilities they allow.

The worlds in our solar system progress from small rocky planets near the Sun to gas giants in the outer system. This progression may be a general rule. The growing Sun drove volatile compounds like water out of the inner planetary system. Perhaps the planets of cool, red stars are more volatile-rich because their parent star was less efficient at drying out the inner system when the planets were forming. This is analogous to the large satellites of the gas giants in our solar system, which weren't desiccated as they formed. But cool red stars have probably gone through a T Tauri phase early in their lives, and this period of intense luminosity should have "dried out" the inner planetary system efficiently.

What differences are likely in another planetary system? One obvious changeable criterion is the size of the planets. Look, for example, at the size difference between the Earth and the Moon — yet both are at the same mean distance from the Sun. It looks as though the sizes and orbital distributions of the terrestrial planets in this solar system are largely the result of chance.

Dynamic variations are also possible. At one time, Mercury was thought to keep one face permanently toward the Sun, as the Moon does toward the Earth. While this was wrong, no doubt such a situation could occur with a planet around some other star. There are other possibilities. While our seasons are caused by the tilt of Earth's rotational axis, seasonal changes could arise just as easily from a planet's highly eccentric orbit. Summer would then occur when the planet moved into the portion of its orbit that carried it nearest the star. Thus, unlike seasons caused by axial tilt, both hemispheres would experience the same season at the same time. The tilt of a planet's rotational axis relative to the plane of its orbit is itself probably determined by chance — by the precise manner in which its last few large planetesimals collided.

A planet around a binary star is a glamorous possibility that has starred in many science-fiction stories. Is it possible? We don't actually know, but it probably depends critically on the separation of the two stars. If the stars are far enough apart, say a hundred times the average distance between Earth and Sun, then planets can probably form around each star as though the other weren't present. The view from a planet orbiting either of the stars would be nice, but nothing really spectacular — the stellar companion would simply appear as a brilliant point, not as a second Sun.

Alternatively, if the stars are very close — say, a few million kilometers — then planets that orbit the pair can probably form. The view from such a world would truly show "twin suns" — a beautiful sight, surpassed only by the frequent stellar eclipses that would take place.

The worst case for planets around binary stars seems to be the one in which the stellar components are separated by about 10 times the Earth-Sun distance — the distance from the Sun to Saturn. The two brightest members of the Alpha Centauri system fall into this category. Some models suggest that planets can't form at all under these circumstances — the orbits of small planetesimals are too stirred up by the stellar masses to coalesce into large bodies.

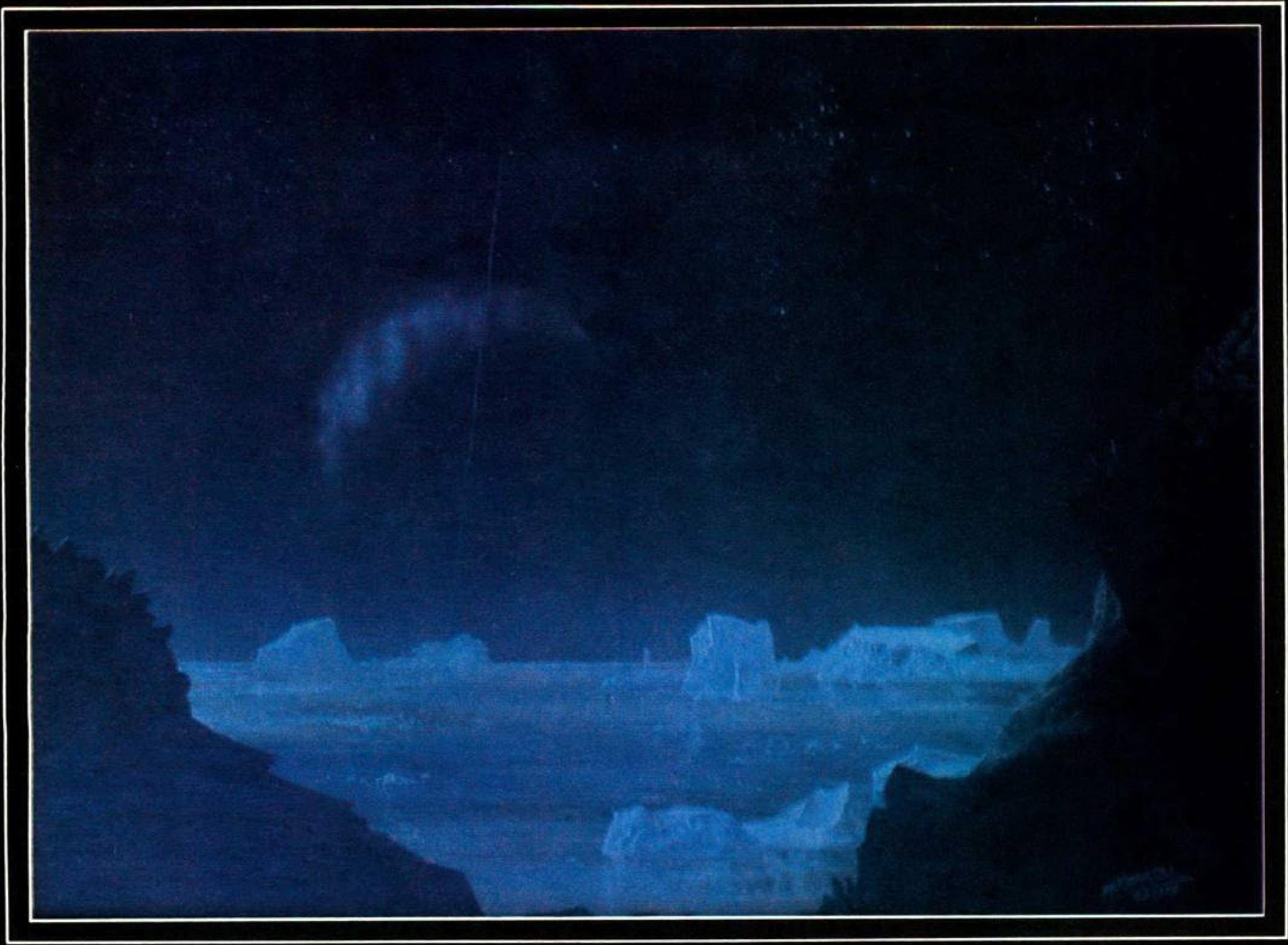
Multiple moons are another science-fiction standard. Mars has two tiny satellites, and the large planets like Jupiter and Saturn have entire miniature solar systems. Why don't terrestrial planets have several attendants? Indeed, perhaps a true double planet, two worlds of similar size circling each other — maybe even two earth-like worlds — is possible. The Earth and Moon are often called a "double planet" because their relative sizes are much closer than any other primary and satellite in the solar system, with the exception of Pluto and Charon. However, they're not *that* close — the Moon still contains only $1/80$ the mass of the Earth. Imagine looking up in the sky and seeing another Earth, with ever-changing clouds, soft green and tawny continents, and brilliant icecaps!

Any plausible configuration of satellites must, of course, be stable over geologic time, a limit not always recognized by fiction writers. Gravitational interactions among the satellites and tidal interactions with the primary severely limit the long-term stability of multiple satellite systems. Still, the unsuspected intricacies of Saturn's rings show that dynamic systems can have long-term stability and yet be a good deal more complex than we thought. Even the very presence of Earth's Moon is difficult to account for theoretically.

Cosmic element abundances also set a fundamental limit: Planets made of platinum-group elements, for example, are unlikely because those elements are intrinsically rare. Such elements are probably rare everywhere because their nuclei are on the far side of the curve of binding energy, beyond the iron-group elements. Still, a great deal of compositional variation is possible, and as I've pointed out, *surface* conditions are sensitive to a minute fraction of the mass of the planet. It shouldn't take much compositional variation to create wide diversity.

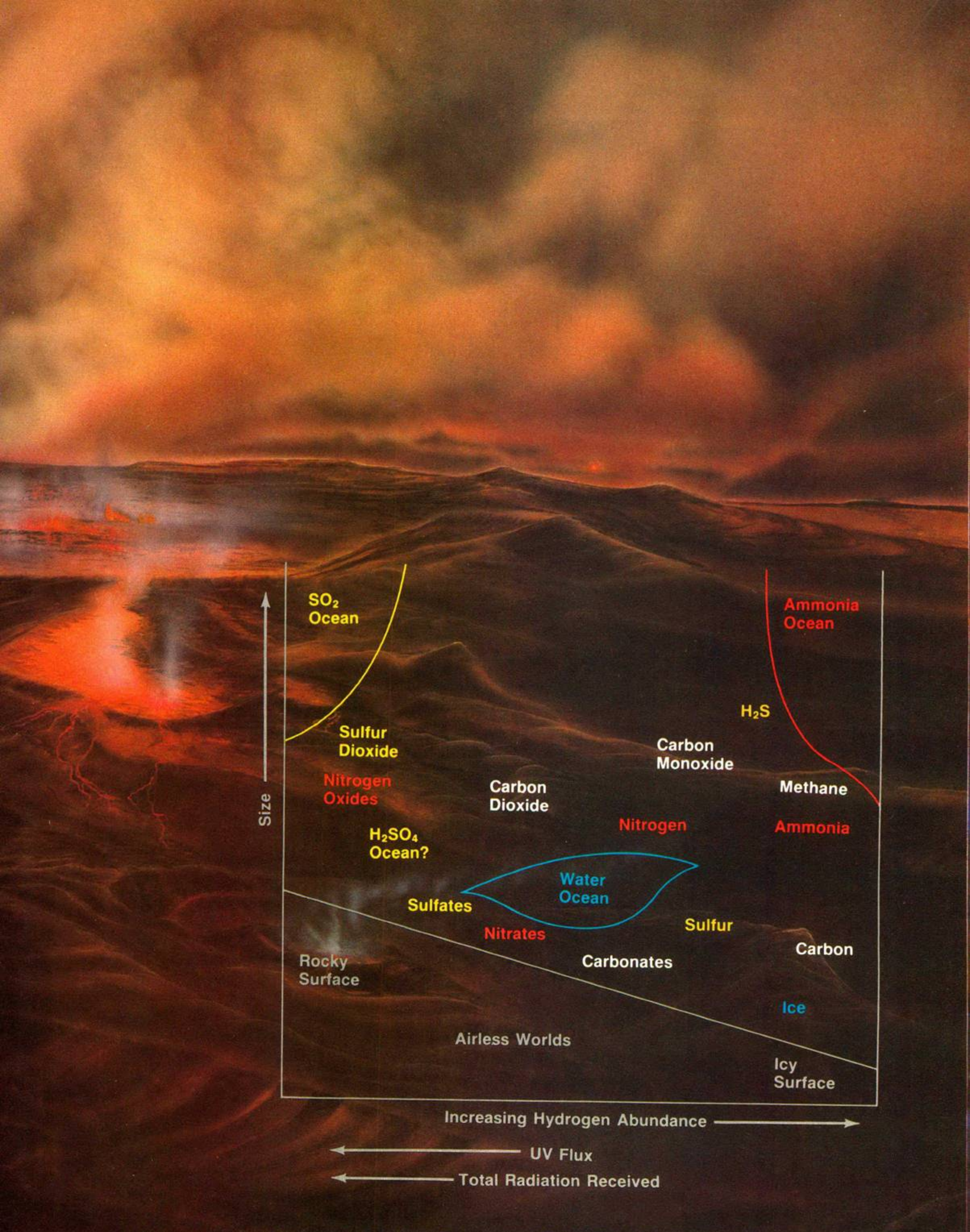
What sort of tectonic processes might rework a planet's surface? Tectonics will depend on both composition and internal heating, which could be supplied by radioactive elements or tides raised by a satellite. Planetary crusts can be either rigid or mobile. Rigid crusts like those of the Moon, Mercury, and Callisto may be relatively simple — some faulting and volcanism occurs early in the planet's history, but it dies away rapidly as the body cools, and the surface preserves an ancient impact record. Some planets, like Mars, will have intermediate crustal activity.

Mobile crusts, however, may be diverse indeed. Internal heating powers the plate tectonics of Earth, but this process requires water in the mantle. Water lowers the melting point of the rock so that it can act as the relatively low-viscosity layer the plates travel over. Plate tectonics is, therefore, self-



Michael Carroll

Icy worlds can support varieties of land forms also. Here a landslide, triggered by seismic activity, has strewn blocks of water ice across a frozen ocean.



Size
SO_2 Ocean
Sulfur Dioxide
Nitrogen Oxides
H_2SO_4 Ocean?
Sulfates
Nitrates
Rocky Surface
Carbon Dioxide
Water Ocean
Nitrogen
Carbon Monoxide
H_2S
Ammonia Ocean
Methane
Ammonia
Sulfur
Carbonates
Carbon
Ice
Airless Worlds
Icy Surface
Increasing Hydrogen Abundance
UV Flux
Total Radiation Received

Sulfurous clouds dim the distant sun of a young, geologically-active world. Painting by Mark Paternostro.

perpetuating — water lost through volcanoes is continually replenished by sea water carried down into the areas where the crust is subducted.

But the heat's got to get out somehow, even when plate tectonics cannot occur. Jupiter's moon Io, for example, disperses its tidally-generated internal heat by continual volcanic resurfacing; something similar may happen on Venus. Volcanos extrude lava, which gradually gets buried more and more deeply under successive flows. Ultimately, deeply buried lava once again melts and flows to the surface. (Could we call this "candle-wax tectonics?") Furthermore, processes like Earth's plate tectonics don't necessarily need water as the lubricating fluid. Most volatiles — like ammonia and carbon dioxide — would profoundly affect the viscosity and melting point of a silicate mantle, also.

What about planets that are almost earth-like? Some models of climate evolution suggest that Earth oscillated between Scylla and Charybdis. A little nearer to the Sun, a little hotter, and Earth would have slipped into a "runaway greenhouse" condition, becoming a duplicate of Venus. A temperature increase evaporates more surface water, and water vapor is one of the gases that retain heat in an atmosphere. Additional water vapor causes temperatures to rise a bit more, so that more water vapor evaporates, and the greenhouse becomes more efficient yet. For a total solar input only slightly higher than that received by Earth, this process does not reach a limit. After the oceans boil away, photodissociation by sunlight would subsequently destroy the steam.

On the other hand, Earth also escaped a runaway glaciation. Once formed, glaciers tend to cool the Earth still further because they reflect incoming solar radiation. The cooling fosters an increase in the size of the glaciers, cooling things still more. A bit farther from the Sun, and Earth could have wound up sheathed in gleaming ice, rather like the jovian moon Europa. Such an ice ball, once formed, appears to be stable — it's too efficient at reflecting sunlight ever to melt again.

As if that weren't enough, the safe zone for Earth's placement in the solar system — its "ecosphere" — is particularly narrow because current astrophysical theories suggest that the Sun has increased its output by about 30 percent since its formation. Not only are conditions okay under today's hotter Sun — they must have been just right under the cooler conditions prevaling billions of years ago.

Adherents of James Lovelock's "Gaia hypothesis" suggest that things were not quite this grim. He argues that feedback in the Earth's biosphere damps out such climatic extremes. However, evolution would have floundered around a bit while devising biological feedback mechanisms to begin with — and Earth's climate must have been relatively stable to have allowed the time for such experimentation.

These ruminations suggest some horrifying possibilities. Not all planets can have been as lucky as Earth. Consider a runaway greenhouse that happened *after* oceans — and perhaps life — formed, as the parent star inexorably increased its light output. Things slowly became warmer and more humid, then suddenly, as the runaway threshold was passed, the seas boiled away. An atmosphere of steam enveloped a newly sterilized world.

In the biological catastrophe that followed, with virtually all life forms swept away, might free-floating, aerial microbes survive? Perhaps, for the carbon dioxide locked away in limestones remains in the rocks when the oceans boil off. This is all we need to avoid an exact duplicate of Venus. Then, as the steam photodissociated to hydrogen and oxygen gas, the atmosphere would thin to a point that the greenhouse no longer supported itself. A little rain might fall again. Tiny, salty lakes would form on the seared world — all that survived of the pre-runaway oceans. At this point, higher life forms might get a second chance, but under considerably less auspicious circumstances.

We can just as easily picture an earth-like world suffering a runaway glaciation. Plate tectonics will probably continue in the ice-coated crust. A planet like Earth has too much internal heat to stop dead, unlike the icy worlds that orbit Saturn and Jupiter. But again, a terrible evolutionary crisis would ensue; the only survivors might be microbes that live on volcanic vents, such as the recently discovered ecologies that thrive at regions where the sea floor spreads. Here pockets of warm, liquid water would form, as the planet's internal heat locally held off the global ice sheet.

Some less harrowing variations on Earth-like planets are also easy to visualize. There doesn't seem to be any reason why an ocean couldn't completely enshroud a planet. That Earth's complement of water just slightly overfills the basins created by sea-floor spreading is probably accidental. In fact, when sea-floor spreading is exceptionally active, the sea floor swells and inundates much of the Earth's continental area. At times in its past, the sea has covered more of our misnamed planet Earth than it does today.

Alternatively, we can consider the other extreme — planets with less water than Earth. Such worlds may have been unlucky, having been allotted less water during formation, or perhaps they became desiccated over geologic time. Possibly, for example, a cold trap is less effective around a star that is hotter and bluer than the Sun. This sounds like an echo of Percival Lowell's ideas of "desertification," the inexorable drying out of a planet, from which he postulated a dying martian civilization forced to distribute the water of its polar caps with a planetwide series of canals. *In extremis*, such a planet could end up with nothing but salty plains to mark former seas. Here we are, back to depressing scenarios again.

Let's now venture into less familiar territory. Airless bodies will probably be fairly common. They will be relatively small, but just how small will depend on their distance from the parent star. Mercury, cooked by the nearby Sun, can't keep an atmosphere at all. Distant and frigid Titan, on the other hand, is similar in size to Mercury and has an atmosphere thicker than Earth's. Many airless bodies will also be heavily cratered because they're small and inactive; exceptions, like Io, will require unusual circumstances.

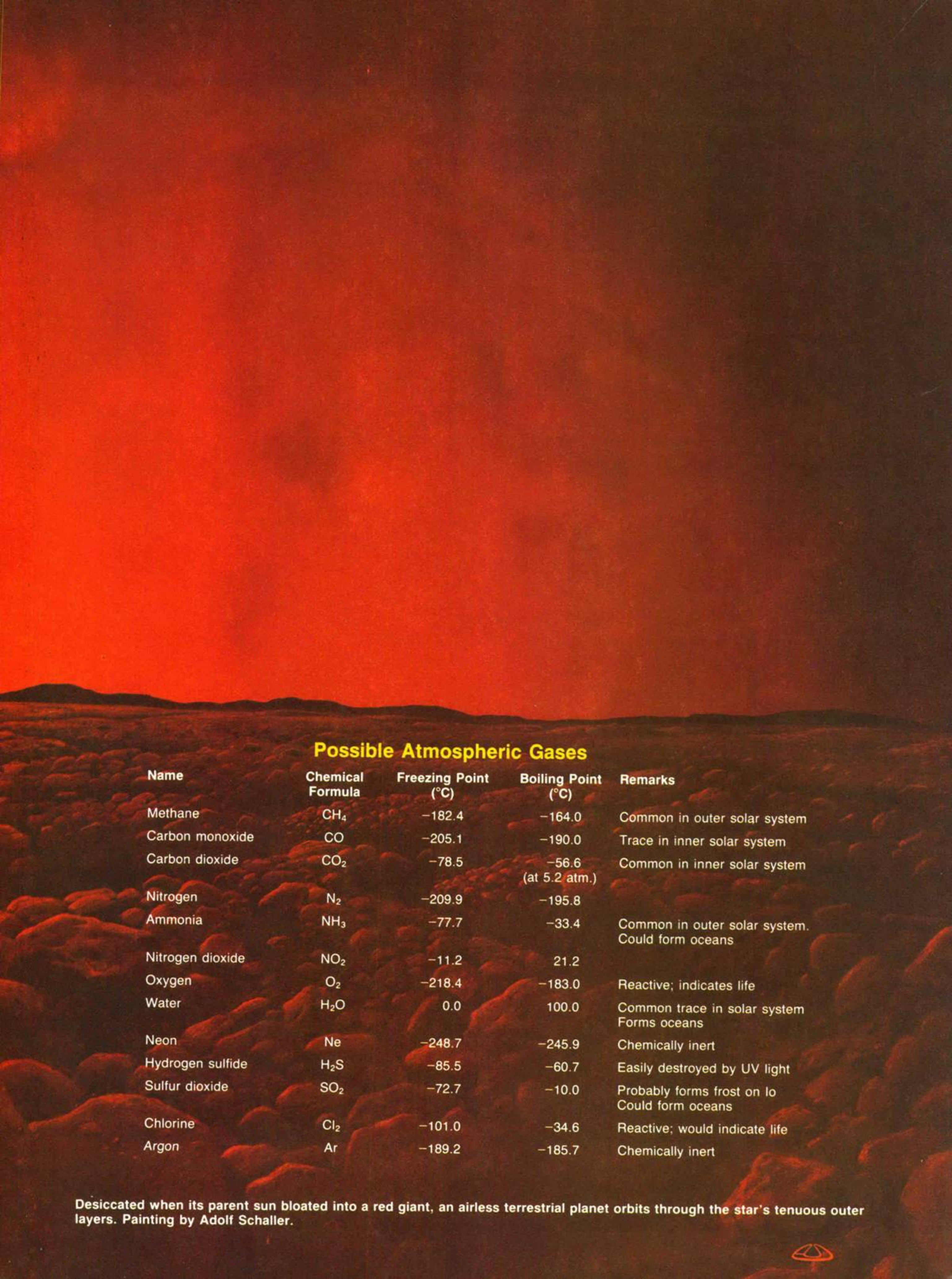
Airless worlds, like our Moon, may be geologically interesting, and perhaps they'll be economically valuable. But airless bodies aren't much fun, so let's turn to worlds with atmospheres.

Drawing on the common elements, gases like methane, chlorine, nitrogen dioxide, argon, and of course nitrogen and oxygen could easily make up a planetary atmosphere. But which of these are the most reasonable?

Large quantities of gases like free oxygen or chlorine may imply the presence of life. This prediction is a corollary of the Gaia hypothesis — "living" planets have reactive gases in their atmospheres and are extremely far from chemical equilibrium. Inert gases like neon and argon will be rare on a terrestrial planet. They don't form chemical compounds and for the most part get driven out before the planets ever coalesce. If they are retained, so are hydrogen and helium — and you've got a gas giant, a Jupiter or Saturn, instead of a terrestrial planet. In fact, much of the Earth's present complement of noble gases is "radiogenic," derived from the decay of natural radioactive elements. The one percent of argon in Earth's atmosphere, for example, comes almost entirely from the decay of potassium-40 in the crust.

The flux of ultraviolet light from the star is another rich source of atmospheric variety. It is obviously related to the total amount of radiation received by the planet, but the percentage of ultraviolet light depends strongly on the spectral type of the star. The planets of hot blue stars will probably be highly oxidized because such stars radiate proportionately more of their energy in the ultraviolet, which efficiently destroys hydrogen-bearing compounds. In contrast, cool red stars may have more chemically reduced, hydrogen-rich planets. But a lot of variation is still possible even within these categories. If you need convincing, just compare Venus, Earth, and Mars — all oxidized planets, by our definition!

The variations introduced by the ultraviolet flux have some interesting implications. One is that those classic science-fiction worlds where ammonia substitutes for water as a biochemical solvent may be hard to stage in the real universe — ammonia



Possible Atmospheric Gases

Name	Chemical Formula	Freezing Point (°C)	Boiling Point (°C)	Remarks
Methane	CH_4	−182.4	−164.0	Common in outer solar system
Carbon monoxide	CO	−205.1	−190.0	Trace in inner solar system
Carbon dioxide	CO_2	−78.5	−56.6 (at 5.2 atm.)	Common in inner solar system
Nitrogen	N_2	−209.9	−195.8	
Ammonia	NH_3	−77.7	−33.4	Common in outer solar system. Could form oceans
Nitrogen dioxide	NO_2	−11.2	21.2	
Oxygen	O_2	−218.4	−183.0	Reactive; indicates life
Water	H_2O	0.0	100.0	Common trace in solar system Forms oceans
Neon	Ne	−248.7	−245.9	Chemically inert
Hydrogen sulfide	H_2S	−85.5	−60.7	Easily destroyed by UV light
Sulfur dioxide	SO_2	−72.7	−10.0	Probably forms frost on Io Could form oceans
Chlorine	Cl_2	−101.0	−34.6	Reactive; would indicate life
Argon	Ar	−189.2	−185.7	Chemically inert

Desiccated when its parent sun bloated into a red giant, an airless terrestrial planet orbits through the star's tenuous outer layers. Painting by Adolf Schaller.

is readily split by energetic photons. Even distant, cold Titan in our own system has had most of its ammonia converted into nitrogen by photodissociation. If ammonia worlds exist, they probably orbit a red star.

The oceanography of an ammonia sea would be bizarre. It would be extremely cold — under the atmospheric pressure at Earth's surface, ammonia boils at −33.4° C and freezes at −77.7° C. Its thermal behavior would be different from a terrestrial sea — frozen ammonia sinks in liquid ammonia, while ice floats on water. This means that an ammonia sea can't be protected from freezing by a skin of ice. Instead, ammonia ice would lie permanently at the bottom of the ocean. And since the temperature range of ammonia's liquid phase is smaller than that of water, somewhere, sometime, some ammonia should freeze and sink.

The sedimentary geology associated with an ammonia ocean would also be totally unearthly. Liquid ammonia is a solvent somewhat similar to water — it's even been extensively studied in the laboratory — but the chemistry of oceans of it would differ greatly from the chemistry of an ocean of water. For example, although water would be frozen out as ice, some of it would react with ammonia to form ammonium hydroxide — the active ingredient in household ammonia solution. Since water is a cosmically abundant compound, the ammonium ion, NH_4^+, should be one of the major dissolved components in an ammonia sea. This ammonium will displace metal ions like the sodium and potassium that occur in Earth's oceans, for they would react with the hydroxide and precipitate out. Sodium hydroxide is lye! It doesn't form on Earth because it's too reactive in a water environment, but it is not soluble in an ammonia ocean. Deposits of marine lye — better be careful picking up pebbles on *those* beaches!

The ammonium ion is chemically similar to the potassium ion. Thus, it will be pervasive in sediments: Ammonium-bearing clays will be ubiquitous; salt deposits of ammonium chloride (sal ammoniac) will precipitate from evaporated sea-ammonia; ammonium carbonate strata might also precipitate, since some carbon dioxide should also be around. Ammonium dissolved in ammonia also acts as an acid, and it reacts readily with metals such as iron. If intelligent life forms do manage to evolve, they'll have difficulty developing a technology.

Let's now slightly increase the ultraviolet flux. As hydrogen is lost, the sort of world that results will depend on what other volatile elements are also present. Were carbon compounds the most abundant, or water, or sulfur compounds? Again, remember that since we're looking at surface phenomena, major fluctuations in *total* planetary composition aren't necessary to give us interesting variations.

If water is the most abundant hydrogen compound, photodissociation leads to an oxygen excess. This has happened to varying degrees on Venus, Earth, and Mars. In this case, the oxidation of carbon compounds makes carbon dioxide abundant. Whether the carbon dioxide stays in the atmosphere (Venus), forms carbonate rocks (Earth), or freezes out (Mars, in part) probably depends on the temperature. Other possible volatiles, such as nitrogen and sulfur compounds, also become oxidized, but they turn into sulfates and nitrates that don't stay in the atmosphere. (As with Earth's atmospheric oxygen, life maintains the gaseous nitrogen — otherwise it would turn into nitrates.)

Now suppose there's not enough oxygen to consume all the carbon, unlike the situation on the inner planets. In this case, carbon *mon*oxide, CO, might become an important atmospheric gas, probably with some CO_2 and nitrogen. Some elemental carbon might occur on the surface, as well as uncombined sulfur instead of sulfates. The most intriguing possibility is that organic compounds might form abundantly on such a planet, by the reaction of water with CO energized by sunlight. Perhaps compounds like formaldehyde, H_2CO, would be significant atmospheric components. If the temperature were just right, such a world could also have water oceans, and some sort of life could evolve.

Titan seems similar to such a planet. It may have thick accumulations of organic compounds on its surface, and it has an atmosphere dominated by nitrogen. Titan, however, is more chemically reduced — the water has not been partly photodissociated; it's been frozen out. No oxygen has been released, so there's no significant carbon monoxide.

Alternatively, if all water becomes destroyed and nitrogen is especially abundant, nitrogen oxides might become important atmospheric constituents. (If there were any water left, it would react with nitrogen oxides to form nitric acid, which in turn forms nitrates.) In the late 1950s and early 1960s, some scientists suggested that poisonous brownish nitrogen dioxide might be a major atmospheric component on Mars. While this isn't true on Mars, it may have happened elsewhere.

Sulfur-rich worlds are another possibility, and Io is the prototype. A reduced (hydrogen-rich) sulfur planet might have a hydrogen sulfide atmosphere, perhaps with methane, ammonia, or nitrogen added in. However, hydrogen sulfide is more readily split by ultraviolet light than ammonia — it's not very likely to be a major atmospheric component.

All is not lost, though. If sulfur atoms outnumber carbon and nitrogen, and if some oxygen is around (perhaps from intense photodissociation of water), an atmosphere of sulfur dioxide, SO_2, might form. Keeping such an atmosphere shouldn't be difficult (although Jupiter's satellite Io doesn't quite manage), for sulfur dioxide is a heavy gas. Such a planet might form around a star bluer than the Sun, where photodissociation is more intense at the same level of total heating. (In case you wondered, hydrogen sulfide and sulfur dioxide can't coexist — they react to form water and sulfur.)

Sulfur dioxide might even form oceans, if the planet were cold enough. The boiling point of sulfur dioxide is −10°C, the melting point, −72.7°C. The temperature range of its liquid phase is greater than that of ammonia, and its boiling point is higher. Further, SO_2 is not vulnerable to loss through dissociation — if split, neither the oxygen nor the sulfur escapes, and they will eventually recombine. The surface of such a planet might contain much elemental sulfur, but not necessarily as much as Io. No one can say whether life could evolve in such a sea; it probably depends on the availability of organic matter. However, like liquid ammonia, liquid SO_2 has been investigated in the laboratory as an alternative to water as a solvent for chemical reactions.

If some water is left on the sulfur-dominated world, oceans of sulfuric acid might form instead. The survival of some water is possible, since the sulfur oxides are hygroscopic and might act as a substitute for the cold trap in Earth's atmosphere, which keeps water vapor from reaching altitudes where photodissociation would destroy it. At least, that seems to have happened on Venus — the last smidgin of venusian water is protected from photodissociation by being tightly bound in droplets of sulfuric acid. If such acidic oceans exist anywhere, any carbon dioxide could exist only in the atmosphere — no limestones could survive. Strong acids destroy carbonate minerals, releasing CO_2. In fact, the standard field test for limestone is to drip acid on the specimen and see if it fizzes.

There are more exotic possibilities, of course. Imagine, for example, a "dry-roasted" gas giant. According to present theories of stellar evolution, after a star like the Sun consumes the bulk of the hydrogen fuel in its core, it swells into a huge red giant. Next to such a bloated star, a planet like Jupiter might not be able to retain its hydrogen and helium, and would gradually wither away into heavier elements. Maybe this is a way to get a neon atmosphere!

After surveying some of the "what might be's," we must conclude with humility. Our solar system is a point of departure, and with it nature has given us just an inkling of her subtleties. And since we can't possibly guess all the variations, we'll just have to look!

Stephen L. Gillett received his Ph.D. in geology from the State University of New York, Stony Brook, in 1981. His major research interest lies in applying paleomagnetism — the fossil record of Earth's magnetic field — to the solution of geologic problems.

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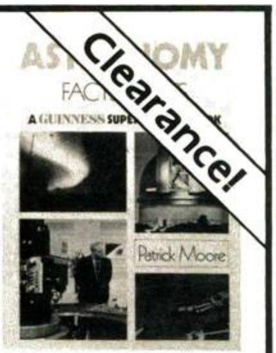

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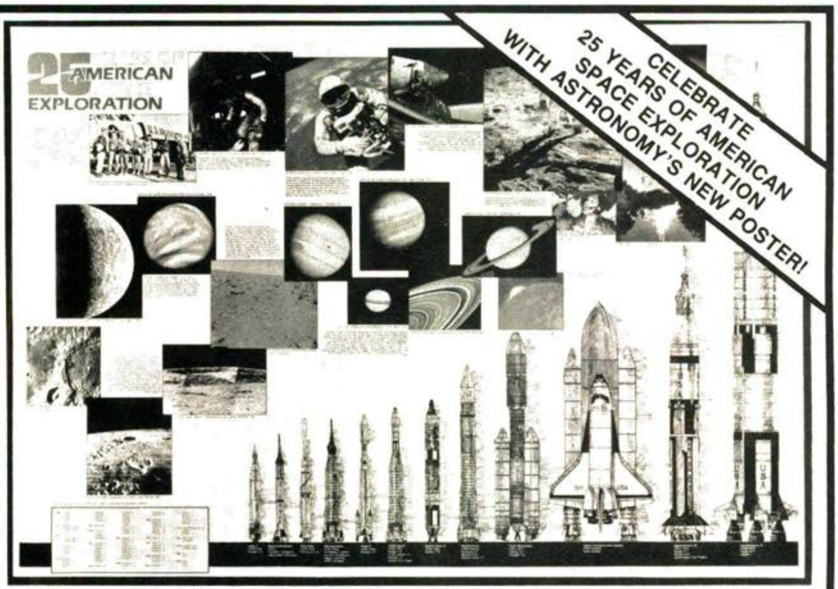
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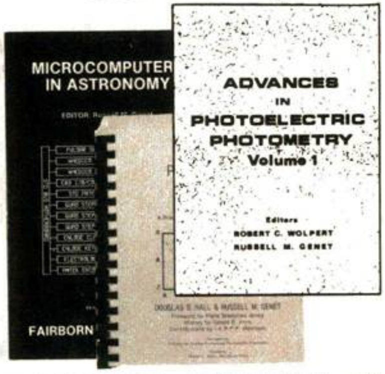
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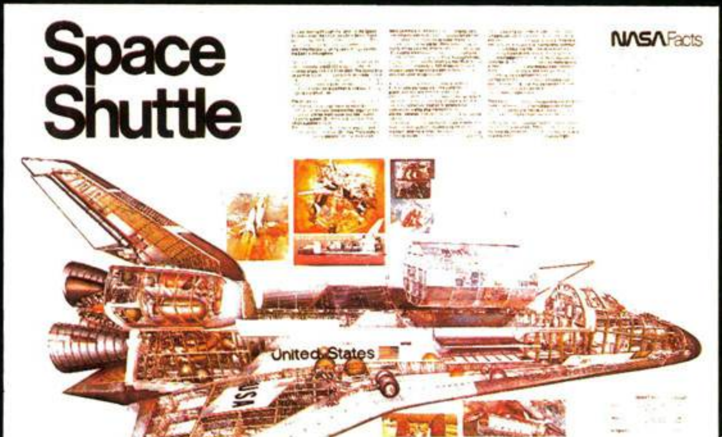

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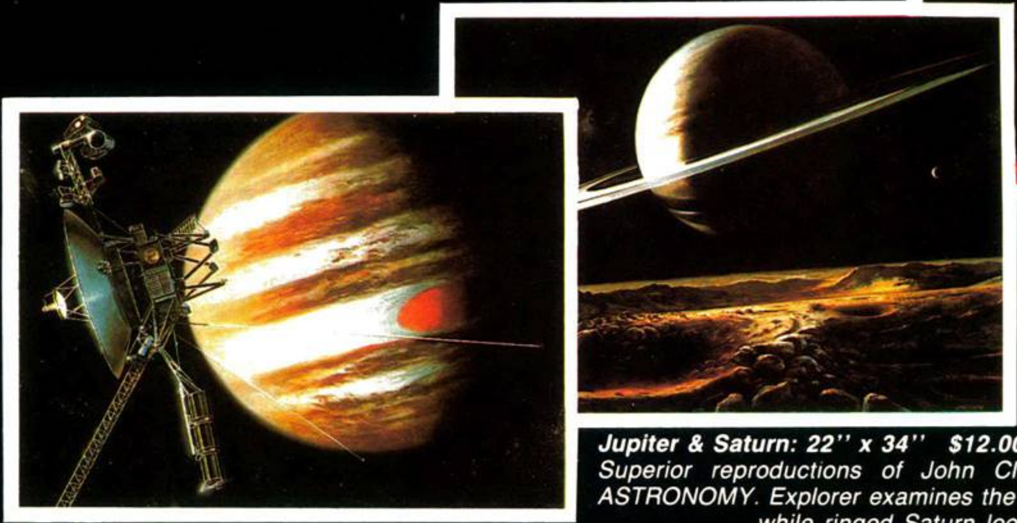

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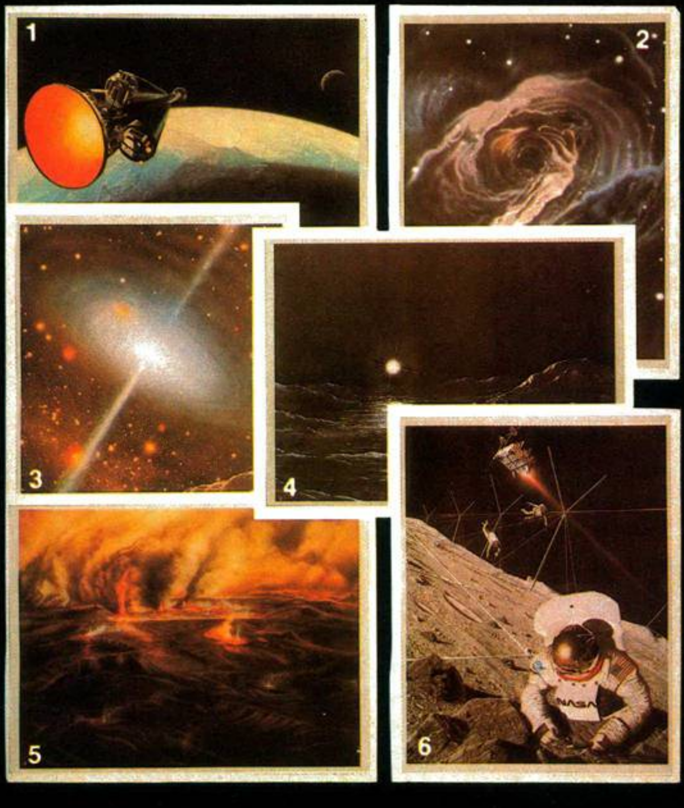

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Photography
in
Astronomy

An Inexpensive Roll Film Holder for Schmidt Cameras

by
Robert Reeves

One of the most exciting astrophotographic developments in recent years has been the availability of fast, high-resolution, commercially manufactured Schmidt cameras. They have allowed the backyard astrophotographer a photographic perfection attainable only by professional instruments in the past. In addition, improved astronomical films such as Kodak's Technical Pan 2415 have allowed Schmidts to resolve finer detail than was possible with the older films.

But the major drawback of these Schmidt cameras has been that you couldn't use roll film with them. Their film holders would accept only one small, single-frame film chip at a time. This has meant you have to develop your own photos, since most processing labs refuse to handle teensy little bits of film.

With the older, non-hypered emulsions, my usual procedure was to store the exposed film chips in a light-tight developing tank until it came time to process them. But this won't do with hypered films. Oxygen and water vapor in the air start fogging the film as soon as you take it out of the hypering tank. Hypering requires you to take your exposure and get the film processed pretty quickly to minimize the film's contact with the air. A chip that sat for several hours in a holding tank whose cover was removed from time to time (as additional frames were deposited) could easily fog up and ruin the image.

At about the same time as I was groping for answers to the "bits of film" problem, I was also looking for a way to use roll film in my Schmidt camera because of its great convenience. Recently one manufacturer marketed an accessory for their Schmidt cameras that allows you to use 35mm rolls — no more fumbling with individual film chips and the film can be sent to a commercial laboratory for processing. To me, this also meant that hypered film could be protected inside a cassette which would help cut down on fogging and would extend the life of a roll of hypered film.

Top: California Nebula (NGC-1499);
Middle: Rosette Nebula (NGC-2237);
Bottom: Horsehead Nebula (B33)

But the holder cost more than I felt I could afford. After mulling the problem over a while, I designed a simple device to take the place of the factory-made roll film holder. Building a duplicate of this device calls for no more than modest mechanical skills and a few dollars in tools and supplies.

Let's start by examining how a roll-film holder works. First, you pass the film leader through the holder, just as you do when loading single-shot film chips. But instead of cutting the film flush with the holder's edge, you leave the supply cassette hanging, attached by the leader. The film leader, extending out the opposite side of the holder, is then taped to the spindle of the take-up film spool and fitted into a reusable 35mm cassette.

This leaves you with two cassettes hanging unsupported from both sides of the film holder. Your next task is to keep the cassettes from flopping down into the light path. My solution was a stiff wire cradle that supported the cassettes.

The tools and materials you'll need are as follows:

1 #29 drill bit
1 #8 x 32 machine screw tap
1 small flat file
1 flat blade screwdriver
1 pair of needle-nose pliers
2 #8 x 32 x ¼'' oval head machine screws
2 flat washers
1 reusable 35mm film cassette
12'' stiff wire at least 3/64'' thick

If you're the tinkering type, you may have most of these already on hand; if not, any well-stocked hardware store can supply you for about $12 to $15.

The conversion procedure is simple. First, remove the pressure plate and locking screw from the holder. Next, drill two #29 holes, one in each side of the film holder, as shown in step 1. After drilling, tap out these two holes with a #8 x 32 tap and carefully file off any burrs from the inside of the film channel.

Next, using two #8 x 32 x ¼″ oval head machine screws and flat washers, secure 6″ stiff wire to each side of the film holder, as shown in step 2. The wire you use must be at least 3/64″ thick to be stiff enough. I got my wire by straightening two thick paper clips, but you could buy some piano wire in a hobby store if you want.

Using needle-nose pliers, bend the wire into a cradle for the two film cassettes, as shown in step 3. Be sure to loop the ends of the wire back so there won't be any sharp ends — you don't want to stab yourself as you work with the thing! Clip off any excess, and check that the wire cradle holds the cassettes straight-on and level as shown in step 3, or they may droop down.

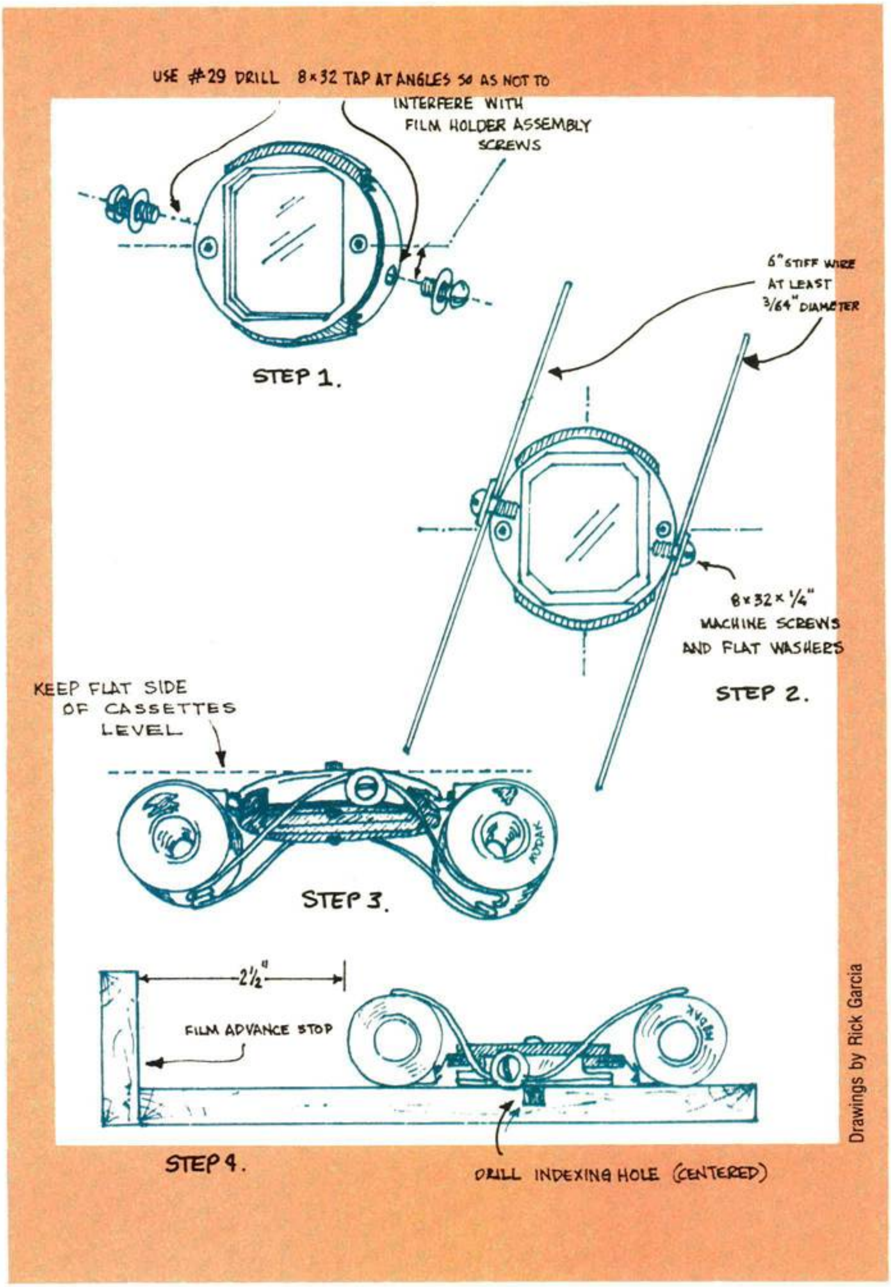
The wire has to be at least 3/64″ thick because it also acts as a spacer between the film holder and the flat washers holding the wire. This 3/64″ space between the holder and flat washers is needed so the dust cover and red filter will fit normally over the holder.

To know how far to advance the film between shots, I made a simple wooden jig, shown in step 4, which I use inside a photographic changing bag. Start by placing the lock screw on the rear of the film holder into the jig's indexing hole. You then draw out the film from the supply cassette a distance of 2½″ as measured by the jig. This distance is enough to prevent overlapping exposures. Loosen the pressure plate and move the film into the holder. Retighten the pressure plate and then wind the exposed film into the take-up cassette. With the dust cover in place, load the film holder into the camera in the dark. (To identify the supply cassette by feel inside the changing bag, mark it with a piece of tape.)

In use, the two cassettes on either side of the film holder block out 10 percent of the incoming light (with an 8-inch Schmidt camera). This means you'll have to extend a 20-minute exposure, say, by a few extra minutes to compensate. For smaller Schmidt cameras, the cassettes eclipse a larger percentage of incoming light and exposures will have to run correspondingly longer. (A little trial and error will tell you how much to allow.) You can paint the cassettes a flat black if you wish, but I haven't bothered to do so. As you can see from the accompanying photos, reflections off the cassettes or support wires haven't created any problems.

Building this little device was fun — and it's brought added pleasure to my astrophotography by making it simpler to operate the camera and easier to develop the film. I hope other Schmidt camera owners will find this system an effective way to increase their instrument's usefulness.

Robert Reeves has been active in astronomy since the late 1950s and has been using his Schmidt camera for 6 years.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8×32×¼″ MACHINE SCREWS AND FLAT WASHERS
STEP 2.
KEEP FLAT SIDE OF CASSETTES LEVEL
KODAK
STEP 3.
2½″
FILM ADVANCE STOP
KODAK
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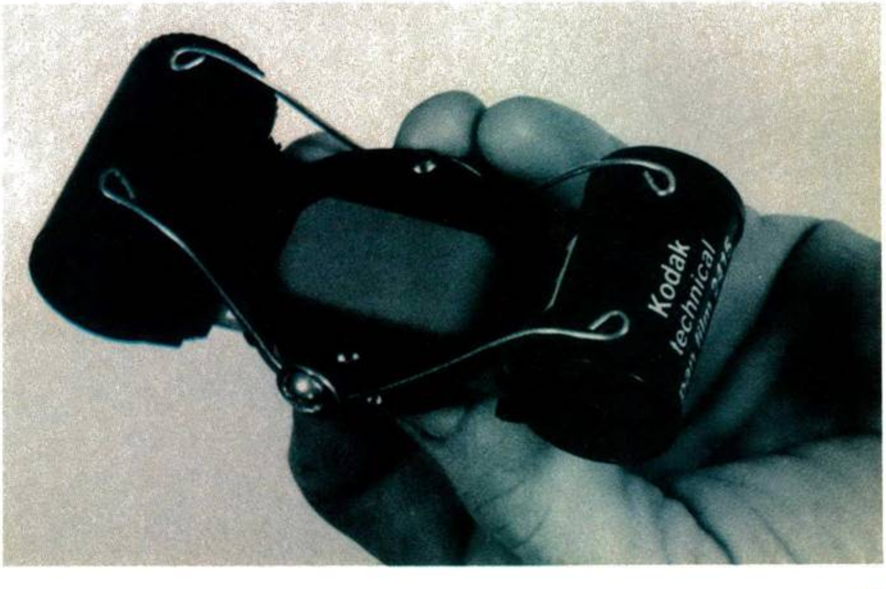
Drawings by Rick Garcia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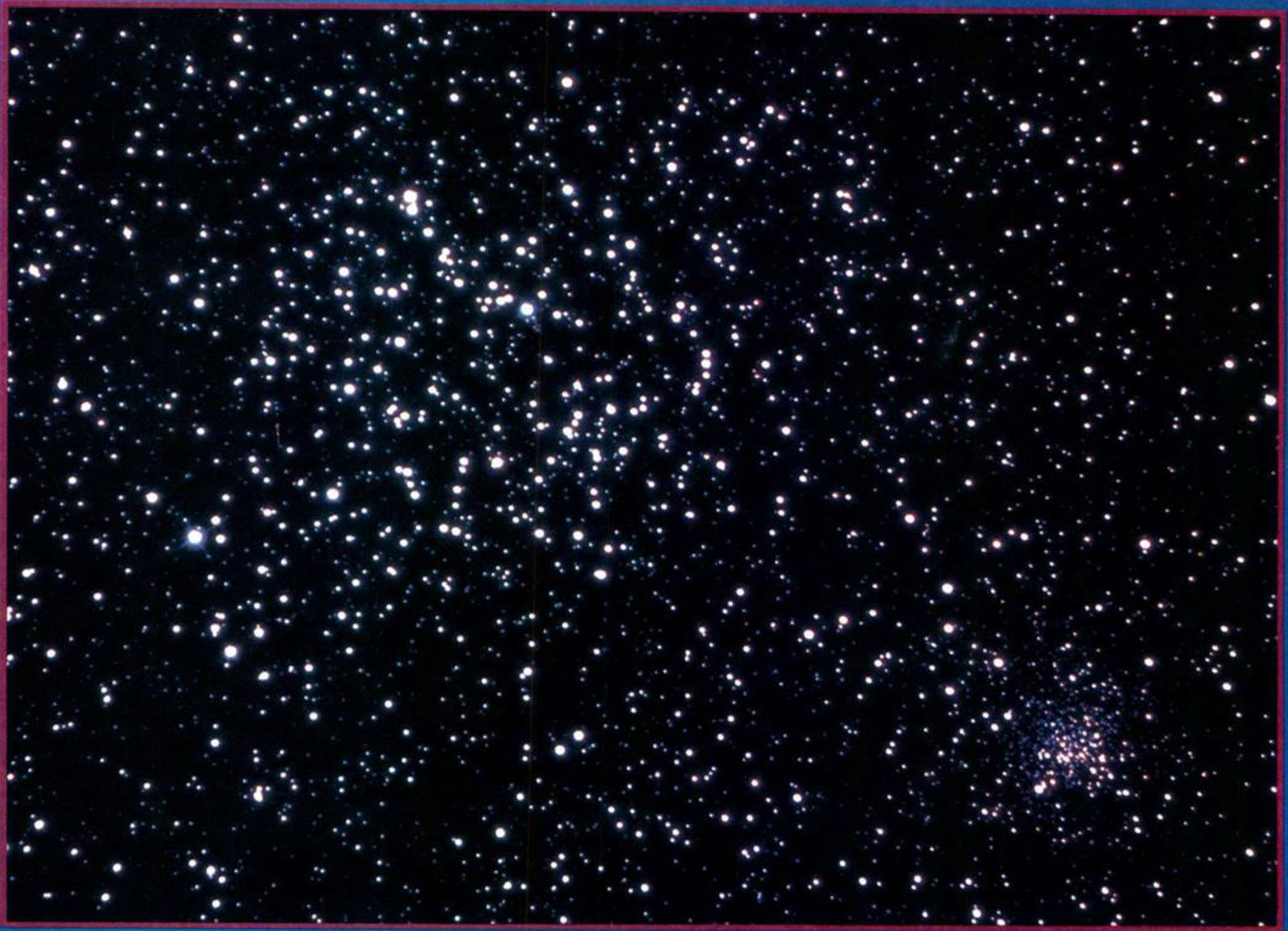
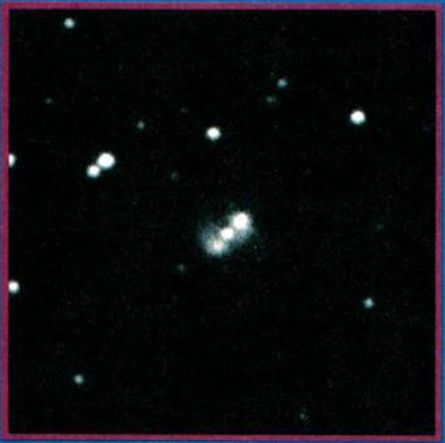
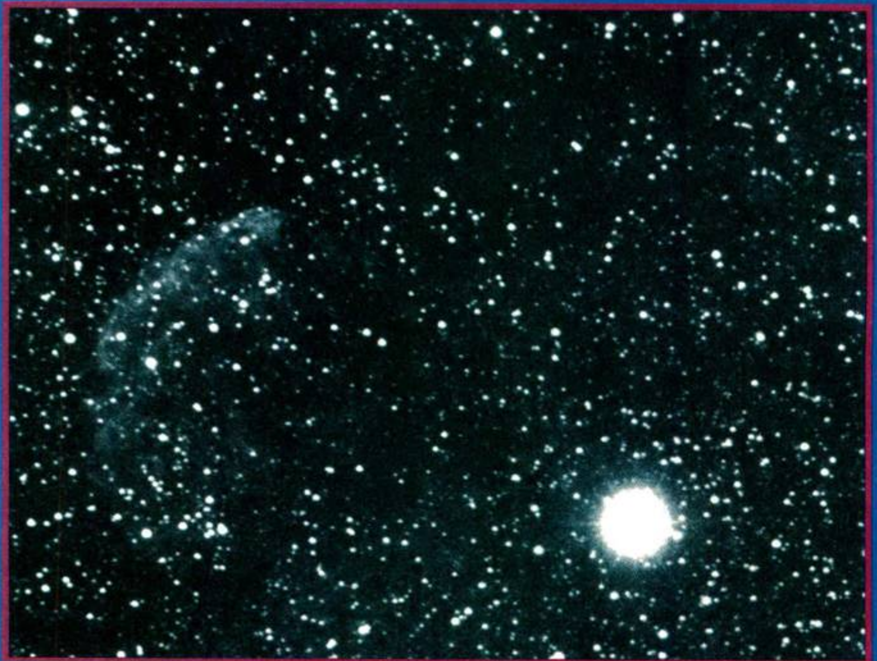




Above: One of the brightest open star clusters, M-35, is visible to the naked eye on dark nights. In this photo by Evered Kreimer, the more distant cluster NGC-2158 lies at bottom right. Below: Supernova remnant IC 443 is an extremely difficult object to observe. The bright star Eta (η) Geminorum lies at bottom right. Photograph by Rick Dilsizian. Bottom left: NGC-2392, the Eskimo Nebula, appears as a bluish-green, out-of-focus star in small telescopes. Photograph by Jack Newton. Middle left: Backyard telescopes show the faint planetary nebula NGC-2371/2 as a tiny double knot of nebulosity surrounding a moderately bright star.

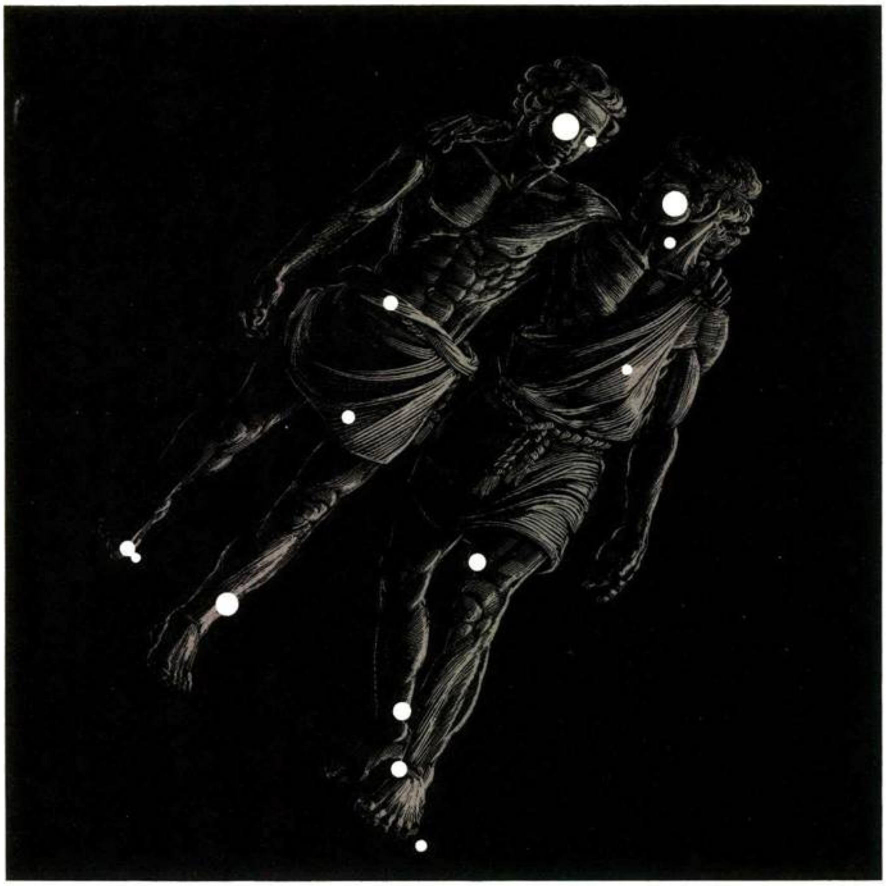


Gemini

Gem
Geminorum

Canis Minor

CMi
Canis Minoris



The region of sky incorporating the constellations **Gemini** the Twins and **Canis Minor** the Little Dog represents one of the richest areas of the winter Milky Way for hunting deep-sky objects. Here, looking away from the Galaxy's nucleus and toward the thick of its Perseus arm, we find nice examples of open star clusters, variable and double stars, and planetary and gaseous nebulae.

The most striking object in this area is the brilliant fifth-magnitude open cluster **M-35** (NGC-2168). This group of 120 stars measures one-half degree across, and its brightest members — B-type main sequence stars and G- and K-type giants — shine with 400 times the luminosity of the Sun, making their combined glow visible to the unaided eye on good nights. A pair of 7 x 50 binoculars shows a rich field surrounding a large misty spot, partially resolved into stars. The cluster's members are evenly spread about its diameter, and there are many bright stars among the faint ones; a 6-inch or 8-inch telescope at low power shows a field full of stars, many arranged in curves and rows, with a bright orange star near the center.

While you're looking through your finderscope at M-35, you may notice a small hazy spot about 30′ to the southwest — this is **NGC-2158**, another open cluster. NGC-2158 appears much smaller, fainter, and less resolved than M-35. M-35 lies only 2,200 light-years away, while NGC-2158 lies at a distance of 16,000 light-years. Here is a chance to observe — side by side — two physically similar objects at dramatically different distances from us.

NGC-2158's 150 stars combine for a total magnitude of 11, and the group's soft glow spans only 4′. It is not an easy target for small telescopes, but is visible nevertheless as a circular nebulous smudge. (The cluster's brightest individual stars are 16th magnitude, making them virtually impossible to distinguish.) NGC-2158 is a "rich" cluster, containing a high density of stars per volume of space, so its surface brightness is high. An 8-inch scope at high power shows a dazzling field of stars around a granular patch, giving a strong impression of great distance. The richness and relative old age of NGC-2158 suggest that it may be a transition cluster between galactic and globular types, but most astronomers class it as a galactic type.

Another nearby open cluster is **NGC-2129**, a small group of 50 stars of 8th to 15th magnitude. Although it is about the same size as NGC-2158, this group shines at seventh magnitude, largely due to a triangle of eighth and ninth-magnitude stars at the group's center. Since most of this cluster's stars are faint, small telescopes show NGC-2129 as a nebulous patch with several bright stars. An 8-inch reflector reveals an irregular mass of faint stars with one apparent double.

About 3° southeast of the M-35 area is the bright double star **Eta** (η) **Geminorum** (also known as Propus), one of the finest in the area for medium-size telescopes. The magnitude 3.3 primary is a type M3 red giant and lies 200 light-years away, making it 160 times as luminous as the Sun. The secondary is a 6.5 magnitude G8-type subgiant star, lying only 1.5″ from the primary at position angle (p.a.) 266°. Thus the star is difficult to split with anything less than a 10-inch telescope. The primary is also a semi-regular variable star with a period of 233 days and a range of almost one magnitude. The entire η Gem system is enshrouded in a cloud of cold gas about 300 astronomical units in diameter.

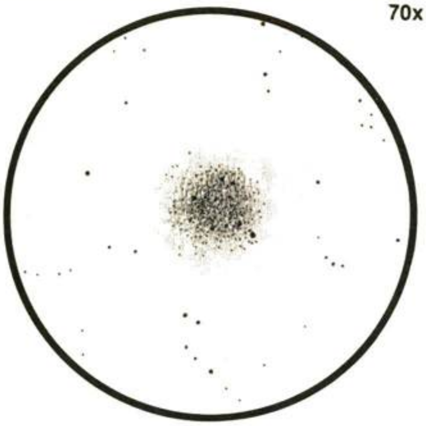
With your telescope centered on η Gem, plop in a low-power eyepiece and swing the telescope 1° northeast. If you are observing in dark skies, you may just pick up the supernova remnant IC 443, a tenuous arc of gas 25′ long. This is a much fainter version of the Veil Nebula in Cygnus, and is probably not visible with anything less than a 12-inch telescope on a night of good transparency.

Three notable planetary nebulae lie within the boundaries of Gemini, each offering a different shape and structure. The brightest is **NGC-2392**, a ninth-magnitude object located midway between Kappa (κ) and Lambda (λ) Geminorum. This object became known as the "Eskimo Nebula" because of its appearance — mottled disk and faint outer ring — on long-exposure photographs. With small telescopes, the Eskimo's diminutive size of 40″ sometimes poses problems to observers hunting with low power; it appears as a tiny, out-of-focus star with a noticeable bluish-green tint. Once you locate it, switch to higher powers which reveal the 10th magnitude central star and fuzzy encircling disk. NGC-2392 is one of the youngest planetaries known, lies at a distance of 3,000 light-years, and measures half a light-year across.

NGC-2371/2 is somewhat larger than the Eskimo and shows a curious double-lobed structure reminiscent of M-76 in

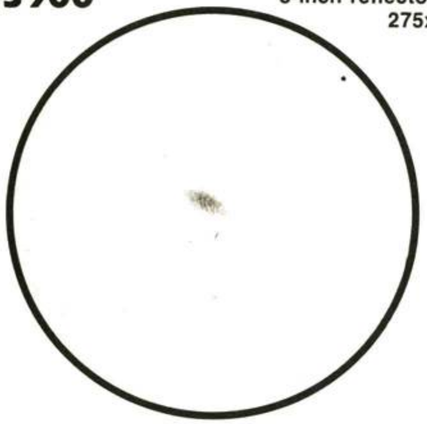
NGC-2158

8-inch reflector
70x



J900

8-inch reflector
275x



Sketches by David J. Eicher

Perseus and M-27 in Vulpecula (hence its two NGC designations). It glows at only 13th magnitude, however, and has a low surface brightness — an 8-inch scope shows two fuzzy half circles almost in contact and the magnitude 12.5 central star. The third planetary in Gemini is the 12th magnitude object **J900**, a tiny dim oval that is not impressive even in medium-size backyard instruments.

Near the region of the Eskimo nebula is the fine double star **Delta** (δ) **Geminorum**, a pair of magnitude 3.5 and 8 stars separated by 6.3″ in p.a. 218°. Also named Wasat, this star is relatively easy to split in small telescopes; its separation of 95 astronomical units is slowly widening; this will eventually make δ Gem even easier to resolve. In February 1930, when Clyde Tombaugh discovered Pluto, the planet lay near this star. (Incidentally, Uranus lay beside the previous double, η Gem, when William Herschel discovered it in 1781.)

East of δ Gem and the Eskimo are two more objects. The first is open cluster **NGC-2420**, a ninth-magnitude group of 30 stars packed into a 7′ diameter. All of the stars in this cluster are faint — 11th to 18th magnitude — so a small scope shows a mottled hazy arrangement of stars and nebulosity. Nearby is the irregular variable star **U Geminorum**, an SS Cygni-type peculiar star that seems to mimic a recurring nova. About once every 100 days, this type of cataclysmic variable can rise from its normal 14th magnitude to 9th magnitude in as little as 24 hours! It then stays at maximum for either 9 or 14 days before fading back to magnitude 14. Astronomers hypothesize that the system contains a red giant star coupled with a tiny blue dwarf and accompanying ring of gas.

One of the brightest stars in this region is **Castor** (Alpha [α] Geminorum), also one of the finest double stars in the sky for backyard observers. The system's total magnitude is 1.6, its components shining at 2.0 (Castor A) and 2.9 (Castor B) and separated by 2.3″ in p.a. 98°. Currently somewhat difficult for small instruments, the separation will widen to a comfortable 4.0″ by the end of the century. A third component, Castor C, shines at ninth magnitude and lies 72.5″ away in p.a. 164°. Yet Castor is not simply a triple star system: Each of the three stars is also a spectroscopic binary, making Castor a system with six suns! Castor A and Castor B are each composed of two A-type main sequence stars; Castor C is a system with two red dwarf stars. All three of the spectroscopic companions are invisible in backyard telescopes.

The final bright open cluster in Gemini is **NGC-2266**, a fairly rich ninth-magnitude group of stars whose individual magnitudes range from 11 to 15. The 35 members are packed into an area only 4′ across, affording a nice view in 4-inch to 8-inch telescopes at medium power.

The plane of the Milky Way is a strange place to go galaxy hunting, but one bright specimen, **NGC-2339**, is located in Gemini southwest of the δ Gem/Eskimo nebula area. NGC-2339 is a type Sc spiral glowing at magnitude 12.5 and measuring 2.0′ x 1.4′ across. It is visible as a faint oval smudge of grey nebulosity in an 8-inch telescope at high power, suspended in back of a rich field of our Galaxy's stars.

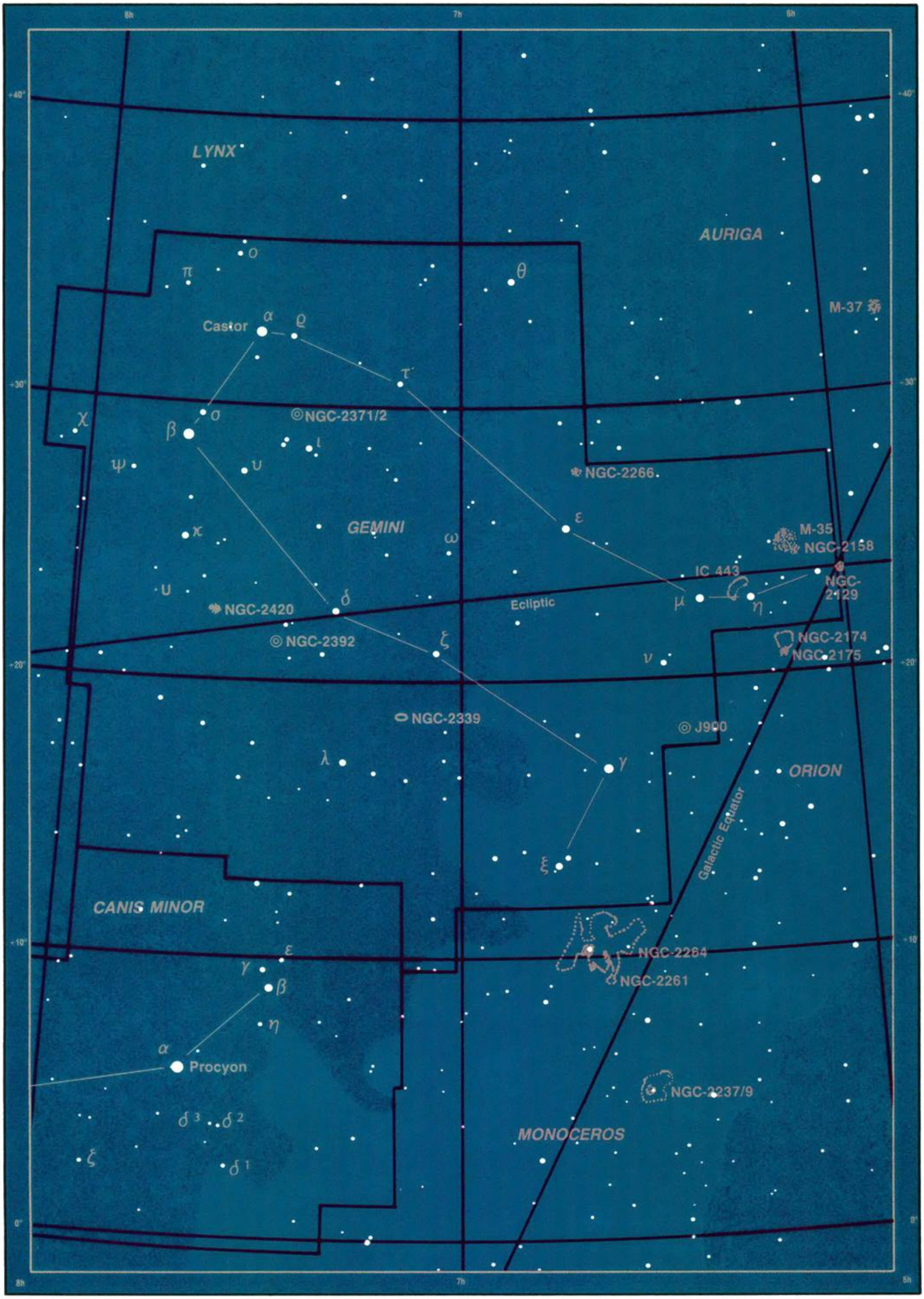
Unfortunately, Gemini's neighbor, Canis Minor, does not contain any nebular deep-sky objects or clusters of stars. Its sole attraction is the bright star **Procyon** (Alpha [α] Canis Minoris), a magnitude 0.4 type F5 subgiant which is the eighth brightest star in the sky. Procyon is a difficult if not impossible double star for amateur observers, not because of its separation — a comfortable 3.9″ in p.a. 113° — but because of the great magnitude difference between the components. Procyon B is a 10th magnitude white dwarf star whose feeble light is simply overpowered by the bright primary.

Gemini and Canis Minor lie in the midst of a rich region. Nearby lie the star cluster M-37 in Auriga, a bright binocular object, and the faint gaseous nebulae NGC-2237/9 (the Rosette Nebula), NGC-2264 (the Cone Nebula), and NGC-2261 (Hubble's Variable Nebula). The Rosette and Cone nebulae surround large bright star clusters, while NGC-2261 is a small triangular patch of misty light.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	N★	Mag.★
NGC-2129		⊙	6h 01m	+23°18′	6.7	5′	50	8-15
NGC-2158		⊙	6h 07m	+24°06′	11.6	4′	150	13...
NGC-2168	M-35	⊙	6h 09m	+24°19′	5.5	30′	120	8...
Eta (η) Gem		SRV	6h 15m	+22°30′	3.1↔3.9	233d		
IC 443		☐SNR	6h 17m	+22°47′	14?	25′x5′		
J900		■	6h 26m	+17°47′	12.0	10′		
NGC-2266		⊙	6h 44m	+26°59′	9.1	4.5′	35	11-15
NGC-2339		∮	7h 08m	+18°47′	12.5	2.0′x1.4′		
Delta (δ) Gem		★^{2}	7h 21m	+21°59′	3.5+8.0	6.3″		
NGC-2371/2		■	7h 26m	+29°29′	12.5	50″x30″		12.5
NGC-2392		■	7h 29m	+20°55′	8.0	40″		10.0
Castor (α Gem)		★^{2}	7h 35m	+31°53′	2.5+3.5	1.8″		
NGC-2420		⊙	7h 38m	+21°34′	9.0	7′	30	10-18
Procyon (α CMi)		★^{2}	7h 39m	+50°14′	0.4+11.0	3.9″		
U Gem		IV	7h 56m	+22°00′	8.9↔14.0	Irr		

★^{2}	*Double Star*
SRV	*Semi-Regular Variable*
IV	*Irregular Variable*
⊙	*Open Cluster*
■	*Planetary Nebula*
☐SNR	*Supernova Remnant*
∮	*Spiral Galaxy*

N★ = number of stars, Mag.★ = magnitude range of cluster or magnitude of central star, (...) indicates many fainter.


8h
7h
6h
+40°
+30°
+20°
+10°
0°
LYNX
AURIGA
ο
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Castor
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M-37
σ
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◎NGC-2371/2
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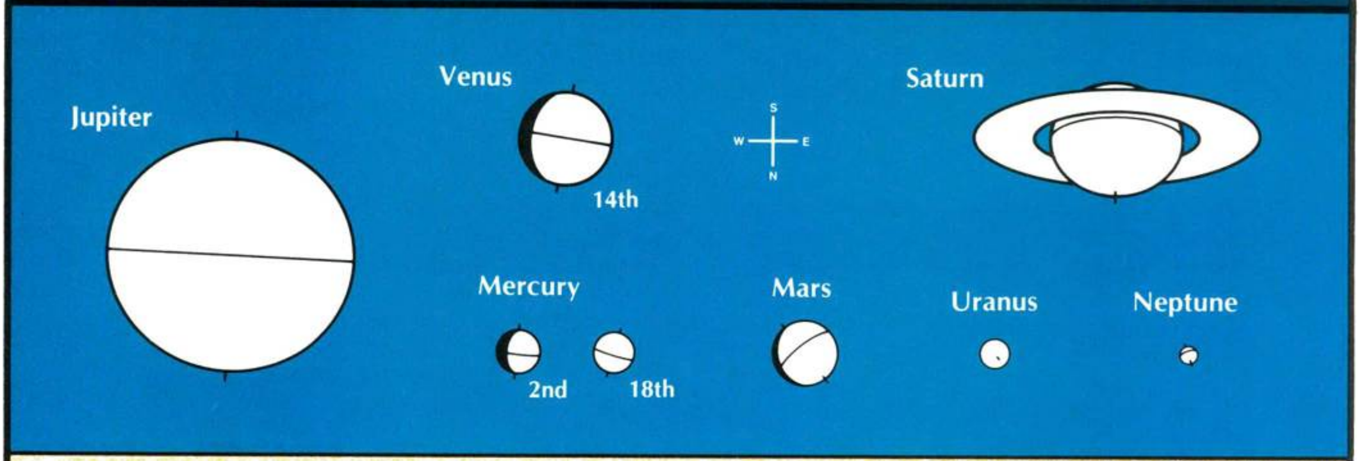
ψ
υ
NGC-2266
GEMINI
ω
ε
κ
M-35
NGC-2158
IC 443
NGC-2129
U
NGC-2420
δ
Ecliptic
μ
η
◎ NGC-2392
ζ
NGC-2174
NGC-2175
ν
NGC-2339
◎ J900
λ
γ
ORION
Galactic Equator
ξ
CANIS MINOR
ε
γ
β
NGC-2264
NGC-2261
η
α
Procyon
NGC-2237/9
δ3
δ2
ζ
δ1
MONOCEROS
8h
7h
6h

Planetary Data February 1984


Jupiter
Venus
14th
S
W
E
N
Saturn
Mercury
2nd
18th
Mars
Uranus
Neptune

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.8	32.5′	—	0.99	—	—	311°19.0′	20h 56.0m	−17°19.6′
		15	−26.8	32.4′	—	0.99	—	—	325°29.9′	21h 51.9m	−12°57.1′
		29	−26.8	32.3′	—	0.99	—	—	339°36.0′	22h 45.4m	− 7°53.5′
Mercury	☿	1	−0.2	5.8″	78%	1.16	0.46	232°33.6′	288°16.4′	19h 22.1m	−22°19.0′
		15	−0.3	5.1″	90%	1.31	0.46	271°24.7′	308°28.8′	20h 48.3m	−19°36.0′
		29	−1.0	4.9″	98%	1.38	0.42	314°18.1′	331°46.2′	22h 20.7m	−12°35.2′
Venus	♀	1	−4.0	12.9″	83%	1.29	0.72	228°35.0′	277°09.3′	18h 33.9m	−22°19.3′
		15	−4.0	12.2″	86%	1.37	0.73	250°53.4′	294°21.8′	19h 47.8m	−20°57.1′
		29	−3.9	11.6″	89%	1.44	0.73	273°05.3′	311°37.0′	20h 59.6m	−17°34.8′
Mars	♂	15	+0.5	8.1″	90%	1.16	1.64	189°46.4′	225°47.9′	14h 58.3m	−15°11.1′
Jupiter	♃	15	−1.9	33.7″	100%	5.85	5.28	267°00.2′	274°47.2′	18h 23.9m	−23°03.6′
Saturn	♄	15	+0.5	17.2″	100%	9.37	9.84	220°37.2′	225°48.7′	14h 59.1m	−14°27.2′
Uranus	⛢	15	+5.6	3.6″	100%	19.27	19.00	250°16.2′	252°29.2′	16h 47.6m	−22°21.2′
Neptune	♆	15	+8.0	2.2″	100%	30.82	30.26	269°17.4′	270°15.9′	18h 04.5m	−22°16.0′
Pluto	♇	15	+13.7	0.1″	100%	29.45	29.84	210°17.1′	211°31.4′	14h 23.8m	+ 3°49.4′

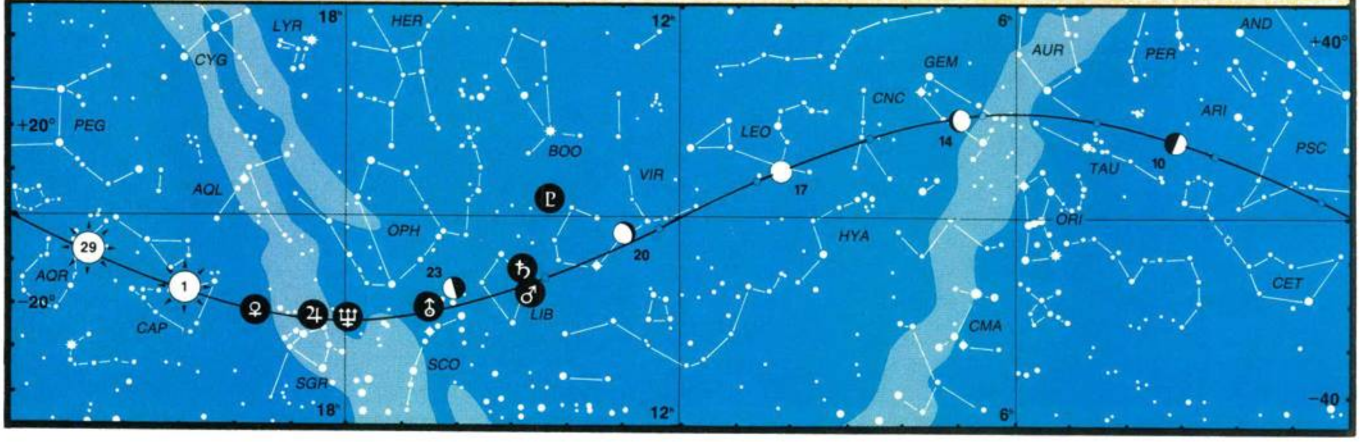
Universal Time

Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24 hour clock. Times in The Backyard Astronomer are UT unless otherwise noted. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska 9; and Hawaii, 10. For example, if an event is to happen at 03:00 hours UT on February 2, then EST for the event is 10 p.m., February 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m, March 4.

Moon Data

New Moon	February 1 at 23:46
First Quarter	February 10 at 4:00
Full Moon	February 17 at 0:41
Last Quarter	February 23 at 17:12
New Moon	March 2 at 18:31
First Quarter	March 10 at 18:27

Apogee: February 4 at 9:00 . . 406,436 km.
Perigee: February 17 at 8:58 . . 356,712 km.


LYR
18°
HER
12°
6°
AUR
AND
+40°
CYG
GEM
PER
CNC
ARI
+20°
PEG
LEO
14
BOO
TAU
10
PSC
VIR
17
AQL
♇
ORI
HYA
20
OPH
29
♄
AQR
23
♂
CET
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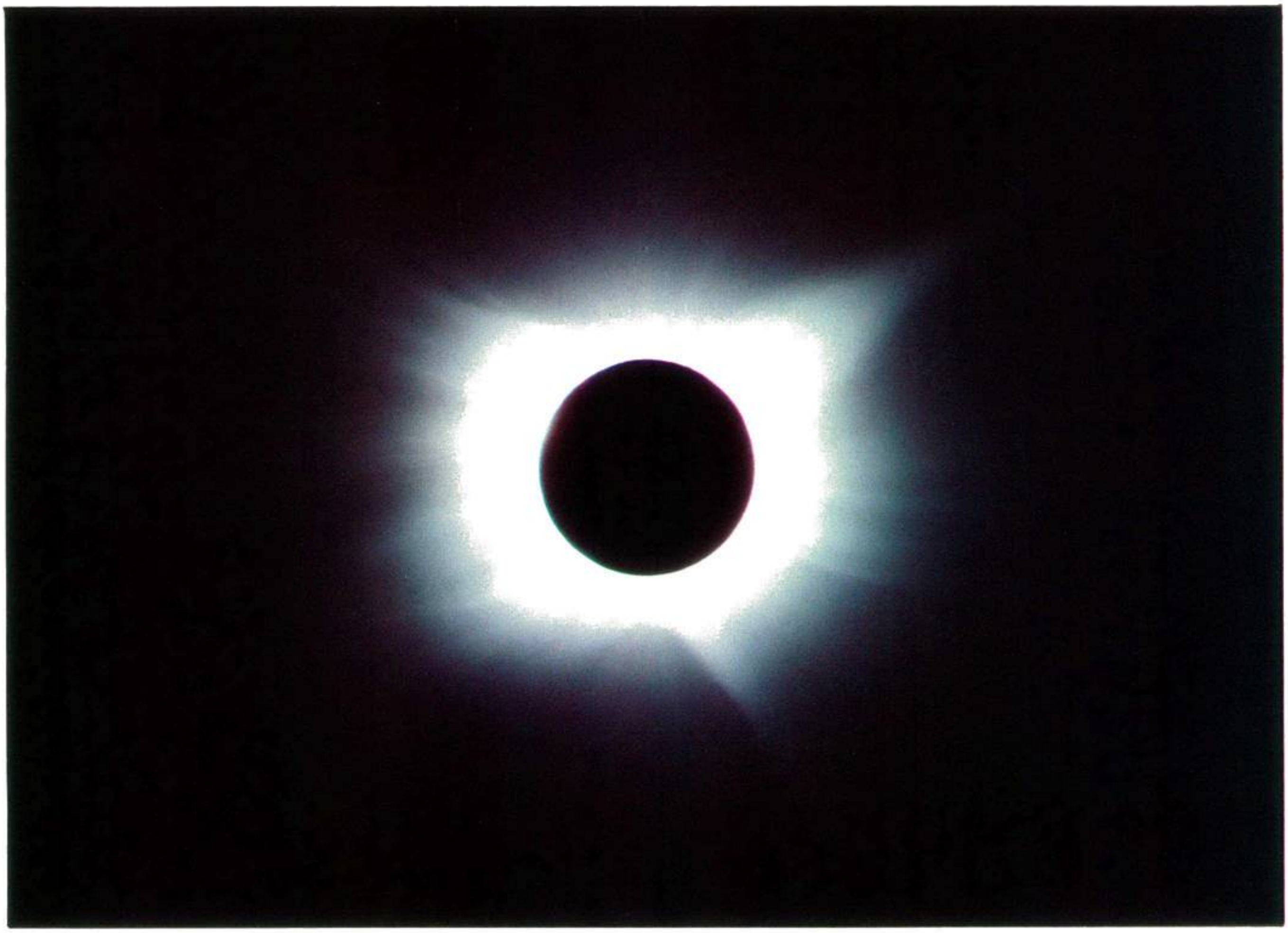
SGR
18°
12°
6°
−40



Brian Tkachyk of Edmonton, Alberta, journeyed to Salatiga, Java, for the total solar eclipse last June 11th. He photographed the eclipsed Sun surrounded by a full corona with a 400mm lens and a 2-second exposure at f/8 on Kodachrome 64 film. Note the wispy structure in the coronal streamers.

Mercury

As February opens, Mercury is only 4° high in the southeastern sky 45 minutes before sunrise. It is sinking lower and lower each day; after the first week or 10 days of the month, it will be too low to be seen. Superior conjunction comes on March 8th, which will be followed by the year's best apparition (in the evening sky).

This month, in your scope, Mercury will appear small and nearly round; its magnitude will be −0.2. Due to its low elevation, your views won't be very good — seeing is always terrible near the horizon.

Venus

Although its −4.0 magnitude brightness makes it easy to spot in the predawn sky, Venus is also sinking lower day by day in the southeast and will be out of view in only a few weeks more. Telescopically, you won't see much more than a disk 12″ of arc across, nearly circular (84% illuminated), and "swimming" in the thick air.

Mars

Mars forms a pair with Saturn this month, when it passes 48′ of arc south of the ringed planet on the 15th. The time of conjunction is 12:39 UT, and the two will have the same brightness — +0.5 magnitude. You can tell them apart because Mars will be ruddier than creamy-white Saturn. Although it will be a pretty naked-eye sight, the two will look even better when grouped together in a low-power eyepiece.

Mars' apparent diameter will be 8.1″ of arc, and Saturn's 17.2″ (the rings spread 39.0″ and are tipped 21° to our line of sight). In the case of both planets we are looking at their northern hemispheres (see diagrams on the opposite page); on Mars the northern summer solstice was passed in mid-January.

Asteroids

1 Ceres and 2 Pallas are too close to the Sun to be seen this month — Ceres is in conjunction on March 22nd and Pallas on February 9th.

3 Juno (magnitude 9.1) lies in eastern Cetus. Its positions:

10th: 3h 00m 29s, +2° 37.2′
20th: 3h 17m 00s, +4° 29.1′

Juno sets around 11:30 p.m. local time on the 15th.

4 Vesta (7.6) is in Taurus to the northeast of Aldebaran. Its positions:

10th: 4h 49m 04s, +20° 54.1′
20th: 4h 53m 45s, +21° 27.1′

Vesta sets around 2:30 a.m. local time in mid-February.

For convenience in plotting their positions in a star atlas, all asteroid coordinates are for the epoch 2000.0.

Jupiter

Rising about 4:30 a.m. local time on the 15th, Jupiter is still only poorly visible in

Totality Ending for Epsilon Aurigae

The eclipsing binary Epsilon (ε) Aurigae has been at minimum light since December 1982. According to predictions, this "total stellar eclipse" will last until January 16, 1984. The star will then begin its return to full light, which it should reach by June 1984. (See "Mystery Star," ASTRONOMY, August 1983.)

Anyone interested in observing this rare event — the eclipses occur at 27-year intervals — should once a week compare Epsilon's brightness relative to its neighbors Zeta (ζ), at 3.8 magnitude, and Eta (η), at 3.2 magnitude. In eclipse, Epsilon is at 3.8 magnitude, but starting in January, you ought to see it begin to change. By early summer it will have returned to its normal 3.0 magnitude brightness.

Above: Leo Henzl's photo of the Horsehead Nebula in Orion shows the dark dust cloud superimposed on the ruddy hydrogen nebula IC 434; at upper left is bluish NGC-2023. Right: February's "Best Astro-Photo" is Joseph Macrie's shot of M-64, the Black-Eye Galaxy, in Coma Berenices. He used an 11-inch SCT at f/7 and an hour's exposure on hypered 2415.

the morning sky by the time the Sun comes up. In your scope, you'll be able to see the four Galilean moons, as well as some banding on the planet. But to explore the intricacies of cloud-top detail further, you'll have to wait a month or so to let Jupiter gain more elevation.

Saturn

Saturn (joined this month by Mars) is the first planet to rise. By dawn it is well on its way to setting in the southwest. Aside from its conjunction with Mars on the 15th (see above), Saturn offers fine views at medium to high powers to all who get up early — or stay up late — to observe it.

On its disk, look for a banded structure, more subtle by far than Jupiter's. Wait for moments of tranquil seeing and then use powers of 150x or more when they occur. Many observers have found that using photo-filters — red, blue, green — helps a lot to increase the contrast between the darker banding and the light planet and render it more visible.

Uranus

Uranus lies about 15 minutes of r.a. to the east and a degree south of the 4.6 magnitude star Omega (ω) Ophiuchi (see the map on page 83 of the January issue). Sweep for it with low power and look for a 5.6 magnitude object with a disk 3.6" of arc across.

Neptune

On February 1st, Neptune will be 40' of arc north of M-20, the Trifid Nebula, in Sagittarius (see page 83 of the January issue). It will remain within a degree of the nebula all month long. Neptune's apparent diameter is 2.2" of arc, and its brightness is 8.0 magnitude.

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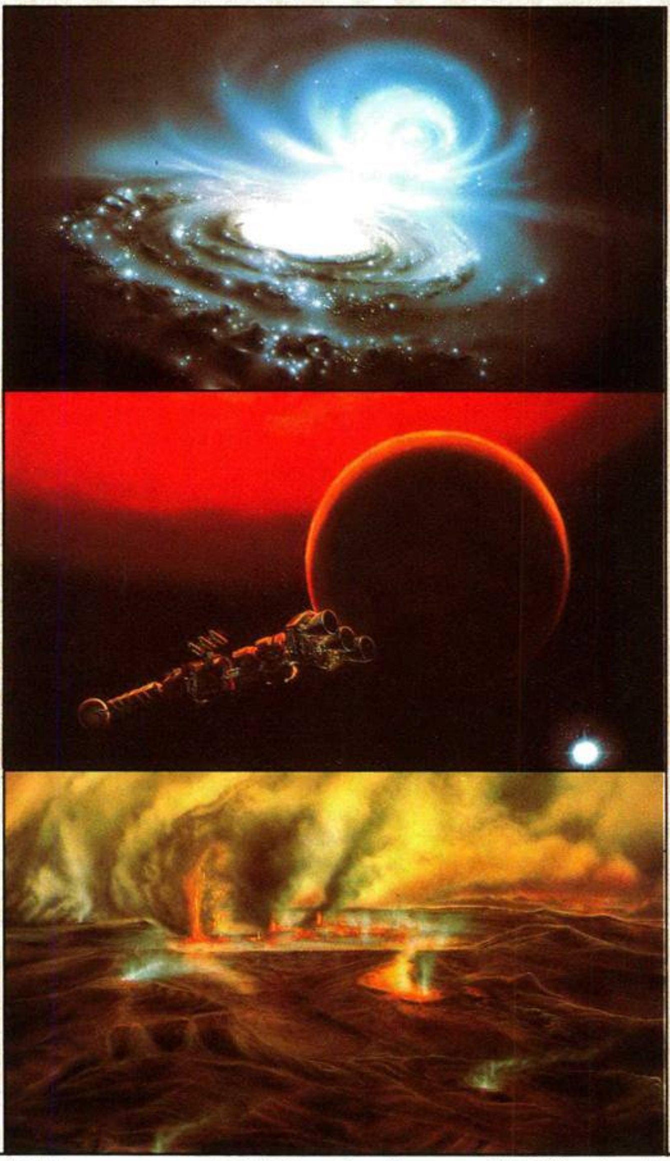

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July 1977, cover

☐AS-02 Martian Duststorm
March 1977, pp. 36 & 37

☐AS-03 Solar Chromosphere
September 1977, p. 35

☐AS-04 Triple Star System
September 1977, p. 12

☐AS-05 Asteroid Belt
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☐AS-06 In The Beginning
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☐AS-18 Planet in Perseus
December 1974, cover

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☐AS-20 Unseen Giant of Cygni A
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Rick Sternbach

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☐RS-03 Erupting Quasar
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☐RS-04 View From Distant Planet
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☐MP-03 Brown Dwarf
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☐MP-04 Swarms of Stars
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☐MP-05 Matter vs. Antimatter
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☐MP-06 Formation of Gas Giant
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☐MP-08 Solar Polar Probe
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☐MP-09 Black Hole
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☐MP-10 Black Hole, Asteroid Collision
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☐MP-11 Collapsing Universe
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Anne Norcia

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☐AN-02 Red Dwarf Explosion
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John Clark

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☐JC-02 Space Telescope
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☐JC-03 Starship to Antares
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☐JC-04 Starship to Zeta Reticuli
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☐LP-01 Saturn From Titan
November 1979, cover

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☐DE-01 Asteroid Miners
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